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OBSERVATIONS ON THE MINERAL METABOLISM OF PULLETS. XII. THE EFFECTS OF PROTRACTED TREATMENT WITH ESTROGEN AND WITH ESTROGEN PLUS ANDROGEN ON RETENTION OF SODIUM

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[Received for publication March 7, 1958]

ABSTRACT

The course of sodium retention by sexually immature crossbred pullets treated with 0.5 mgm. estradiol benzoate (ODB) per day or with 0.5 mgm. ODB plus 0.4 mgm. testosterone propionate (TST) per day did not differ significantly from the course of sodium retention by untreated control pullets. The average daily retention by the pullets from 11 to 15 weeks of age was 37 mgm. Na per day.

INTRODUCTION

The metabolism of calcium and phosphorus by the fowl has been reviewed by Branion (2) and more recently by Tyler (11, 12, 13). Interest in the subject continues, as may be seen from the papers by Taylor and Moore (9, 10). Studies of sodium metabolism in the fowl have been less numerous. Balance methods have been used to study the effect of the level of sodium in the diet on the metabolism of calcium and phosphorus in pullets that were coming into lay (3). Sjollema (8) used balance determinations in a study of the effects of diets of very low sodium content on growth of chicks. He showed that the sodium content of the excreta fell to extremely low levels when the dietary sodium did not exceed 0.013 per cent, but that even at this low level the sodium balance did not become negative. He concluded that sodium is retained obstinately even when the sodium intake is low.

Both estrogen and androgen appear to be involved in the increase of retention of Ca and phosphate that precedes the onset of laying in the fowl (5). Treatment of the immature pullet with estrogen may produce an immediate but transient increase in Ca retention, but if androgen is given concurrently with the estrogen, then the increase in Ca retention is sustained (7). More recently it has been shown that the transient increase of Ca retention induced by estrogen is followed by lowered Ca retention as compared with that of untreated control pullets. After about 10 days, the Ca retention recovers and after a further 10 days or so approaches that of the control pullets (6). The marked increase of Ca retention evoked by treatment with estrogen plus androgen continues up to around the tenth day, after which it declines slowly, though it remains higher than in

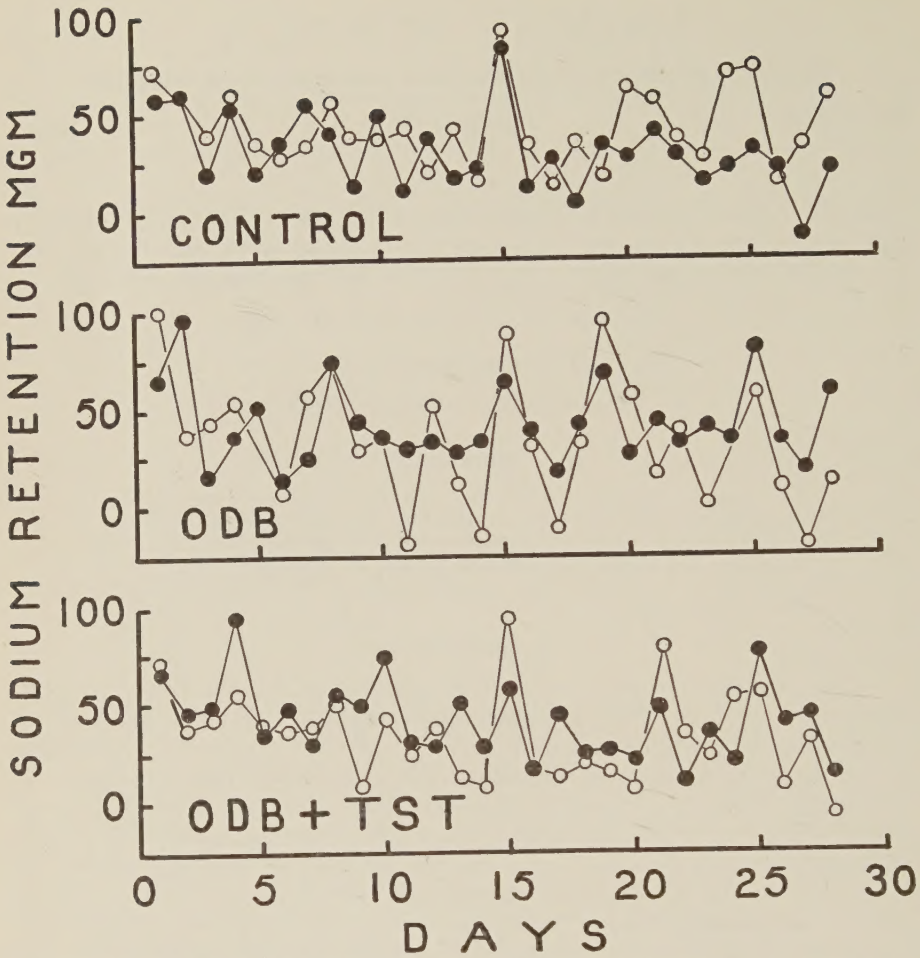

FIGURE 1. Effects of administration of estradiol benzoate (ODB) and of estradiol benzoate + testosterone propionate (ODB + TST) on Na retention by immature pullets. First dose of hormones was given at zero time, i.e., at the beginning of Day 1.

untreated control pullets even after a further 14 days. In view of these striking differences, and also in view of the changes in hematocrit value evoked by estrogen (4), it seemed desirable to extend the observations reported in the foregoing paper by determination of the sodium balance.

MATERIALS AND METHODS

The experimental birds comprised six selected crossbred pullets [Rhode Island Red X (New Hampshire X Barred Plymouth Rock)], 15 weeks of age at the end of the experiment.

The details of the experiment have been described fully in a previous paper (6). It will suffice here to note again the experimental treatments: Pullets 1 and 4 received no hormonal treatment; birds 2 and 5 received 0.5

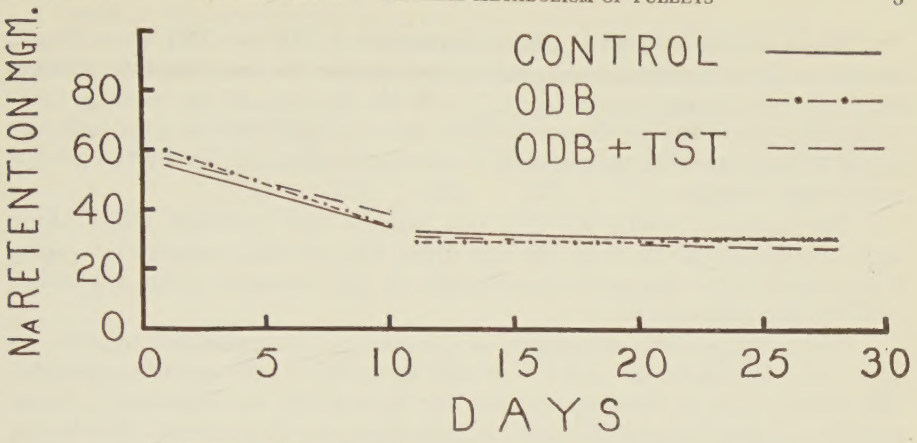

FIGURE 2. Mean linear regressions of Na retention on time.

mgm. estradiol benzoate (ODB) daily; and birds 3 and 6 received 0.5 mgm. ODB plus 0.4 mgm. testosterone propionate (TST) daily. The hormones were given in oily solution by intramuscular injection. The Na content of the ration was 0.48 per cent.

Determinations of Na were made on the dried droppings and the diet by the flame photometric method of the Association of Official Agricultural Chemists (1). Check determinations on extracts that were combusted with nitric acid before flame photometry gave substantially the same results as when this step was omitted.

EXPERIMENTAL RESULTS AND DISCUSSION

The results for the sodium balance are presented in Figure 1, which has been drawn so as to permit comparison with the results already reported for Ca retention (6). The mean linear regressions of Na retention on time are presented in Table I and in Figure 2. The data for Na retention for day 15 were anomalously high in pullets 1, 4, 5 and 6; no explanation could be adduced for this and the data were retained in the statistical computations.

The retention of Na by the control pullets declined fairly steadily over the first 10 days. The regression attained significance at $P = 0.10$. From day 11 to day 28 the Na retention showed a slight but non-significant tendency to decline.

TABLE I.—LINEAR REGRESSIONS OF Na RETENTION (IN MGM.) ON TIME (IN DAYS) FOR SEXUALLY IMMATURE PULLETS TREATED WITH GONADAL HORMONES

Pullets	Treatment	Days 1 – 10 inclusive Regression	t	Days 11 – 28 inclusive Regression	t
1 & 4	nil	$Y = -2.2061 \times + 55.9335$	1.96*	$Y = -0.1383 \times + 34.8077$	0.67
2 & 5	ODB	$Y = -2.8485 \times + 62.6667$	2.02*	$Y = +0.1858 \times + 27.0999$	0.82
3 & 6	ODB + TST	$Y = -1.6061 \times + 57.4335$	1.33	$Y = -0.2012 \times + 33.4241$	1.04

* Significant at $P = 0.10$

The results for the two pullets that received ODB + TST were closely similar to those for the control pullets, but the decline over the first 10 days did not attain significance even at $P = 0.10$. In spite of the much greater total retention of Ca by these two birds than by the controls over both the initial 10 days and the subsequent 18 days, retentions of Na by the groups were closely similar.

The average results for the two pullets that received ODB alone were closely similar to those for the other two groups, except that pullet 5 displayed wider day-to-day variations in Na retention than any other pullet in the experiment.

The average daily retentions of Ca and Na are presented together in Table 2. The data for days 1-10 and days 11-28 are given separately. The higher Ca : Na retention ratios for days 11-28 are obviously almost entirely a reflection of the lower Na retention over this period. Similarly, the higher ratios in pullets 3 and 6 as compared with pullets 1 and 4 are a reflection of the greater Ca retention in this group.

The proportion of the Na retention that went to new bone mineral was probably small, and most of the Na retention must have been utilized for normal growth of tissues other than bone. Data for the Na content of the whole skeletons of poultry obtained by modern methods do not appear to be available. Taylor and Moore (10), however, have reported data for the Ca and Na content of various bones of hens. Their values for air-dry cortical bones and for dry, medullary bone (separated by sedimentation in carbon tetrachloride) suggest that the average ratio Ca:Na is of the order of 43.4. If it be assumed that Ca retained by the birds studied in the present work was incorporated in new bone having this ratio Ca:Na, then it is possible to make an estimate of the amounts of the Na retained that went to bone. The calculated figures are included in Table 2.

These estimates suggest that only about one-third of the sodium retained is likely to have gone to the bones, and that the higher daily Ca retention of pullets 3 and 6 as compared with pullets 1 and 4 would only represent an extra retention of Na by the bones of the order of 3 mgm. Na daily. This would correspond to an increase of total Na retention of the order of 10 mgm. Na. Balance methods should be precise enough to detect an increase of Na retention of this size. They ought certainly to be capable of detecting any marked effect on the gross sodium balance conditioned by the endocrine salt regulatory mechanism. The data afford no significant evidence that the hormonal treatments in the present experiment exerted any such effect.

The average Na retention by all six pullets over the entire 28 days of the experiment was 37 mgm. Na daily. The birds increased from an average weight of 1.09 kgm. to 1.50 kgm. during this period.

CONCLUSION

It may be concluded that treatments with estrogen, or with estrogen plus androgen, that were capable of modifying rather profoundly the course of Ca retention by the immature pullet were without apparent effect on the course of Na retention.

TABLE 2.—DAILY RETENTION OF CALCIUM AND SODIUM BY PULLETS TREATED WITH GONADAL HORMONES

Treatment	Pullet No.	Average daily retention Ca, mgm.		Average daily retention Na, mgm.		Average daily retention ratio Ca:Na		Estimated Na laid down in bone per day, mgm.*	
		Days 1–10	Days 11–28	Days 1–10	Days 11–28	Days 1–10	Days 11–28	Days 1–10	Days 11–28
nil	1	259	254	41	24	6.3	10.6	6.0	5.9
	4	255	243	47	41	5.4	5.9	5.9	5.6
	Av.	257	249	44	32	5.8	7.8	5.9	5.7
ODB	2	206	247	46	40	4.5	6.2	4.7	5.7
	5	254	188	48	21	5.3	9.0	5.9	4.3
	Av.	230	217	47	31	4.9	7.0	5.3	5.0
ODB + TST	3	397	341	55	35	7.2	9.7	9.1	7.9
	6	393	343	42	24	9.4	14.3	9.1	7.9
	Av.	395	342	49	30	8.1	11.4	9.1	7.9

* Estimated on assumption that ratio Ca:Na is 43.4 for bones of the pullet

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THE ESTROGEN-LIKE SUBSTANCES IN CERTAIN LEGUMES AND GRASSES

I. THE QUANTITATIVE DETERMINATION OF SUCH SUBSTANCES IN RED CLOVER AND OATS[1]

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[Received for publication October 3, 1958]

ABSTRACT

A 3-day *per orum* procedure, using female mice 20-21 days old and weighing 8-12 gm., was evolved for the determination of the estrogen-like substances in forage. With diethylstilbestrol (D.E.S.) as reference compound a dose response curve was constructed. From this curve the estrogenic activity of plant material was estimated and expressed in terms of D.E.S. Studies were undertaken to determine the effects of stage of maturity and frequency of cutting of first- and second-year growth of red clover and first-year growth of Victory oats. The samples from first- and second-year growth of red clover possessed considerable estrogenic activity. The level of activity was highest in the spring and decreased towards the autumn. Victory oats possessed little or no estrogenic activity at any time during the growing season.

INTRODUCTION

The presence in plants of substances that are capable of inducing estrus in animals was first reported in 1926 (14). Since that time, extracts of many species of plants have been studied and a large number of these have been shown to exhibit varying degrees of estrogen-like activity. In 1946 Bennetts *et al.* (6) reported that the subterranean clover of Western Australia had sufficient estrogenic activity to impair the reproductive performance of grazing ewes and to cause genital and mammary stimulation of wethers. The effects on livestock production of natural and synthetic compounds having hormonal activity have been reported (19, 20, 21). These reports have led us to the investigation of a legume and a cereal typical of those grown in British Columbia in order to determine whether they possess hormone-like activity and to determine the extent to which the amount of activity changes in relation to stage of growth and the time of harvesting.

To initiate such an investigation it was necessary that a satisfactory method be sought for the determination of the estrogen-like substances in plant extracts. According to Martin and Cook (15) all of the official preparations of estrone, estrodiol benzoate, estradiol and diethylstilbestrol (D.E.S.) are assayed by chemical or spectrophotometric methods. In the case of compounds of uncertain chemical constitution, such as the plant estrogens, a number of bioassays have been used (20). Most of these are modifications of the method developed by Allen and Doisy (3, 4) and further elaborated by Emmens (8, 9, 10, 11). They depend for their response parameter upon the change produced in the vaginal mucosa of spayed rats or mice subsequent to parenteral administration of estrogenic substances. The large number of sequential assays envisioned in the

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TABLE 1.—CONSTITUENT COMPOSITION OF THE BASAL RATION

Constituent	Pounds
Ground hulled oats	52.50
Ground wheat	26.25
Fish meal (70 per cent)	8.75
Meat scraps (55 per cent)	3.75
Skim milk powder	7.50
Steamed bone meal	1.00
Iodized salt	0.25
	100.00

present study pointed up the advantage that would accrue if a simple and rapid bioassay procedure involving the *per orum* administration of plant extracts to intact animals could be evolved.

The basic assumptions that are made in establishing a satisfactory bioassay procedure have been concisely stated by Wood (23). With the guidance provided by his statement, a number of preliminary experiments were effectuated to develop a bioassay procedure and to construct a suitable dose-response curve. The procedure devised and its application to representative plant extracts are the subjects of the present paper.

MATERIALS AND METHODS

A. *Plant Material*

First- and second-year La Salle red clover was cut from 9 ft. × 9 ft. plots established in three randomized blocks. Victory Spring oats were grown in 20 ft. × 6 ft. plots in three blocks. The red clover plots were laid out on Ladner clay loam, and the oats on Alderwood sandy loam in the Lower Fraser Valley area.

B. *General*

The plant material used in the experiments was dried at 150°F. immediately after harvesting. It was then ground in a Wiley mill to pass a 0.060″ screen. The estrogenic substances were removed from the dried forage samples by twice refluxing with 95 per cent ethanol (16). The combined extracts were concentrated under vacuum and were then added to a basal mouse ration (Table I) such that one gram of ration contained the alcoholic extractives from one gram of the original dried plant material. The basal ration was formulated to meet the maintenance needs of the mouse within the limits imposed by the need to have the basal ration free of estrogenic activity. The dearth of knowledge on the estrogenic substances in dried plant material precluded the addition of the usual grass or alfalfa meals as sources of unknown factors in the basal ration.

Diethylstilbestrol (D.E.S.)*(U.S.P.) was once recrystallized and then used in all experiments as the bioassay reference substance.

Randomly selected immature female mice (8–12 gm.) of the U.B.C. Swiss Albino strain were used as the assay animals.

*Nutritional Biochemicals Corporation, Cleveland, Ohio.

RESULTS AND DISCUSSION

A. *Evolution of the Bioassay Procedure*

1. *Feed intake of immature female mice over a 3-day period*

Since the assay procedure was to be predicated upon *per orum* administration of the plant extract, it was necessary to determine the normal feed consumption of the mice under our conditions. Over a 3-day period, 21-day-old mice in the weight range 9.3 to 10.6 grams consumed between 7.9 and 9.2 grams of the basal ration. When the animals were fed the basal ration containing plant extract, food intake was reduced to between 5.5 and 6.5 grams. Alexander and Watson (2) have reported a similar self-imposed restriction of feed intake by guinea pigs receiving a ration supplemented with dried subterranean clover.

2. *The rate of passage of feed in immature female mice*

The time required for feed to pass through the gastro-intestinal tract will determine, in part, the amounts of nutrients and other substances absorbed. Since the proposed assay period was of 3 days' duration, it was important to make certain that the entire allotment of feed was ingested and offered an opportunity for absorption within this time interval. The time of passage of the basal ration was found to be approximately 8 hours. Similar results were obtained using chromic oxide or ferric oxide as feed markers at the 0.1 per cent level. From the mean passage time recorded it is apparent that the assay animals may be killed 8 hours after the last feed is consumed.

3. *The influence of time of fasting on uterine weight of immature female mice*

As the response parameter selected was uterine weight expressed as a per cent of body weight it was necessary to determine the influence of the duration of fast prior to sacrifice on the body weight of the animals and hence on their relative uterine weights. The animals were fed 5 grams of feed over a 3-day period and were then fasted for 0, 8 and 24 hours. They had access to water at all times.

TABLE 2.—THE INFLUENCE OF "ASSAY LENGTH" ON THE UTERINE WEIGHT AS A PER CENT OF BODY WEIGHT

Ration	Group	No. of animals	Hours on ration	Hours of fasting	Average body weight at end of fasting (gm.)	Average uterine weight (mgm.)	Uterine weight as per cent body weight
Basal	1	12	24	8	10.35	17.65	0.17 ± 0.007*
	2	10	48	8	10.45	20.50	0.19 ± 0.009
	3	12	72	8	9.51	16.73	0.17 ± 0.010
Basal containing 0.05 mcgm. D.E.S. per gm. of feed	4	12	12	8	10.45	26.37	0.25 ± 0.008
	5	12	24	8	10.35	27.65	0.26 ± 0.006
	6	12	48	8	10.43	37.13	0.35 ± 0.016
	7	12	72	8	10.02	40.28	0.40 ± 0.017
	8	12	96	8	10.40	36.18	0.34 ± 0.014
Basal containing red clover extract (1st cutting May 3, 1957)	9	12	12	8	11.90	40.30	0.34 ± 0.016
	10	12	24	8	10.00	30.97	0.31 ± 0.011
	11	12	48	8	9.69	44.54	0.46 ± 0.023
	12	12	72	8	10.34	51.58	0.50 ± 0.021
	13	12	96	8	10.27	50.76	0.49 ± 0.010

*Standard error

The duration of fast following the consumption of the basal ration supplemented with D.E.S. had relatively little effect on the uterine weight when expressed as a per cent of body weight. As one would expect, the mean body weight and the mean uterine weight of the mice decreased as the fasting time increased. Over the time interval studied the weight loss of the uterus paralleled that of the mouse from which it was recovered. An 8-hour fasting period was selected for all subsequent assays. Dissection of the uterus free of extraneous tissue is facilitated following 8 hours of inanition.

4. *The length of the bioassay period*

The duration of the assay period was studied to determine if normal estrus in the immature mice could interfere with the response to the compounds under assay. Assays were carried out in which the period ranged in length from 12 to 96 hours. The results of this study (Table 2) indicate that the relative uterine weight of the control animals did not change during a 72-hour assay period. Had natural estrus intervened within this time interval its presence would have been manifested by a *dramatic increase* in uterine weight. Other studies have shown that estrus does not occur in our strain of mice until a body weight of 16 grams or more is reached. The uterine weight increases from approximately 32 milligrams in the anestrus state to about 76 milligrams with this first normal estrus. On the other hand, those animals fed the basal ration supplemented with D.E.S. or a measured amount of plant extract showed a maximum relative uterine weight response at 72 hours. The anomalous result obtained in the red clover series when the animals were fed for 24 hours cannot be explained.

Stob *et al.* (19) showed, using ovariectomized mice, that a 3-day assay period was sufficient to measure maximum activity of an estrogenic substance. Alexander and Watson (1) have observed, using spayed guinea pigs, that most if not all of the increase in their uterine weight occurred over the first 2 days when the animals were fed subterranean clover. The present data confirm those of Stob *et al.* (19), and of Alexander and Watson (1), and suggest that a 72-hour assay period is satisfactory.

B. *Construction of the Dose-Response Curve*

From the results obtained in the aforementioned experiments a dose-response curve was constructed using D.E.S. Known quantities of this compound dissolved in ethanol were added to the standard diet. The assay mice were each fed 5 grams of diet for 3 days and then were fasted for 8 hours. Each mouse was weighed and then sacrificed under ether to permit recovery of the uterus. Extraneous material was carefully dissected from the uteri before they were blotted on filter paper to remove free moisture. Twelve animals were used in each assay for each level of D.E.S. The response curve (Figure 1) represents the results from several assays carried out over a period of 6 months. The linearity of the dose-response line over the dose range 0 to 0.080 mcgm. D.E.S./gm. diet appears to be satisfactory. The standard error of $\pm$ 0.019 is not unreasonable for an assay of this type. The inevitable loss of weight which occurs during

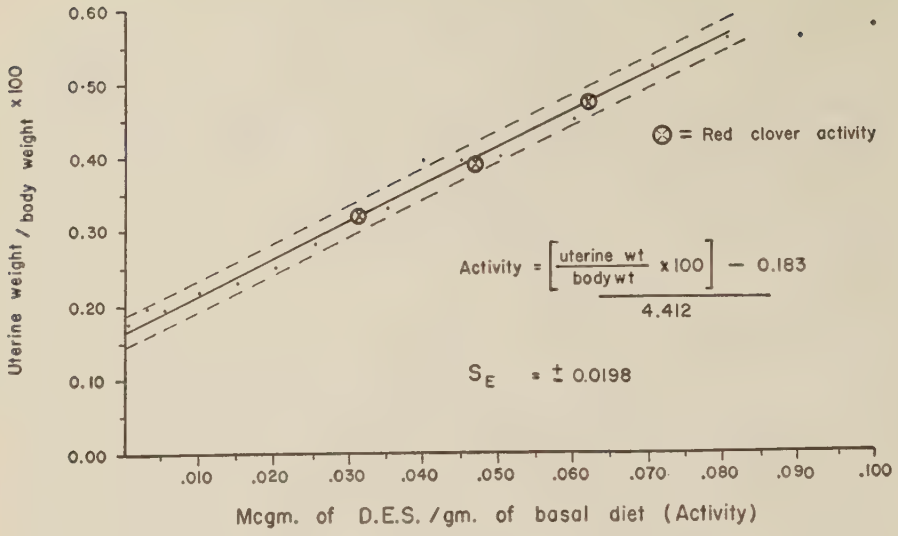

Figure 1. Dose response curve.

the weighing of fresh tissues could produce considerable variability in the recorded uterine weights. The extent of this variation should be a function of the time required to recover the uterus and the time required for weighing. The average length of time required to remove the gland from the abdominal cavity, free it from extraneous material, blot with filter paper and weigh on a previously calibrated spring balance was 40 seconds. The agreement obtained between triplicate determinations suggests that the method used here allows for minimum error arising from moisture changes in the excised uteri.

Since one cannot, on an *a priori* basis, assume corresponding linearity of response to various levels of the unknown estrogenic substances in plant material, a dilution assay of red clover extract was conducted. For this purpose red clover extract-feed mixture was diluted by one-quarter and one-half of its original extract concentration with additional basal diet, and assayed for activity. The result obtained (Figure 1) shows that a linear relationship exists between the concentration of the estrogen-like substances in the clover extract and uterine relative weight to body weight. It would appear that one can assay unknown plant materials against the D.E.S. dose-response curve.

C. *Estrogenic Activity of Red Clover and Oats*

1. *The effect of stage of maturity and frequency of cutting on the estrogenic activity of red clover*

Red clover has been shown, by other bioassay procedures, to possess estrogen-like substances (16, 20). However, the levels of the active substances reported vary considerably. These variations may be due to anomalies of the bioassay used or to the stage of maturity of the forage and the season of the year when the forage was harvested.

To date, three compounds showing estrogenic activity have been isolated from red clover. In 1953 Pope *et al.* (17) isolated biochanin A and in 1954 genistein (18). The third isoflavone, formononetin, having very little estrogenic activity was isolated in 1953 by Bate-Smith *et al.* (5).

Assays were conducted on red clover extracts to determine the effect of stage of maturity and the frequency of cutting on their estrogenic activity. The results obtained for first cuttings of red clover at different stages of maturity from second-year growth (1956), and the activity of first, second and third cuttings of this forage (second year) are given in Table 3. Corresponding values for first cuttings for first-year growth of red clover at different stages of maturity (first-year growth, 1957) and the activity of first and second cuttings (first-year growth, 1957) are given in Table 4.

All of the samples of first- and second-year growth possessed considerable estrogenic activity. The level of estrogenic substances was highest in the spring and decreased towards the autumn. Samples of first-year growth of 1957 were relatively higher in activity than the samples from the second-year growth in 1956 cut in the same week of each year. However, the former samples were in the reproductive stage while the

TABLE 3.—THE EFFECT OF MATURITY AND FREQUENCY OF CUTTING ON THE ESTROGENIC ACTIVITY OF RED CLOVER (SECOND-YEAR GROWTH, 1956)

Plot	Cutting	Date of cutting	No. of mice	Uterine weight as per cent body weight	Estimated potency per lb. dry matter in terms of D.E.S. (mcgm.)
A	1	May 2	8	0.56 ± 0.02*	34
B	1	May 25	8	0.59 ± 0.01	36
	2	July 18	8	0.57 ± 0.04	34
	3	Sept. 2	8	0.42 ± 0.02	15
C	1	June 18	8	0.48 ± 0.01	33
	2	July 18	8	0.49 ± 0.03	22
	3	Aug. 18	8	0.33 ± 0.02	9
D	1	July 2	8	0.49 ± 0.02	30
E	1	July 18	8	0.39 ± 0.02	14
F	1	Aug. 18	8	0.28 ± 0.01	6
G	1	Sept. 2	8	0.25 ± 0.01	5

*Standard error

TABLE 4.—THE EFFECT OF MATURITY AND FREQUENCY OF CUTTING ON THE ESTROGENIC ACTIVITY OF RED CLOVER (FIRST-YEAR GROWTH, 1957)

Plot	Cutting	Date of cutting	No. of mice	Uterine weight as per cent body weight	Estimated potency per lb. dry matter in terms of D.E.S. (mcgm.)
A	1	Aug. 15	12	0.36 ± 0.02*	18
	2	Sept. 25	11	0.32 ± 0.02	15
B	1	Sept. 25	11	0.36 ± 0.02	18

*Standard error

TABLE 5.—THE EFFECT OF MATURITY AND FREQUENCY OF CUTTING ON THE ESTROGENIC ACTIVITY OF VICTORY OATS

Plot	Cutting	Date of cutting	No. of mice	Uterine weight as per cent body weight	Estimated potency per lb. dry matter in terms of D.E.S. (mcgm.)
A	1	June 29	8	0.24 ± 0.02*	6
	2	July 31	8	0.29 ± 0.02	11
B	1	July 3	8	0.31 ± 0.01	13
	2	Aug. 14	8	0.27 ± 0.02	9
C	1	July 10	8	0.31 ± 0.02	13
D	1	July 17	8	0.26 ± 0.01	8
E	1	July 24	8	0.20 ± 0.02	<5
F	1	Aug. 7	8	0.30 ± 0.01	12
G	1	Aug. 21	8	0.23 ± 0.01	<5

*Standard error

latter were past bloom. Legg *et al.* (13) made similar observations and postulated that the level of estrogenic substances was associated in some way with the reproductive status of the plant material from which they were recovered.

2. The estrogenic activity of oats

The effect of stage of maturity and frequency of cutting on the estrogenic activity of oats was determined and it was found that little to no activity was present at any time during the growing season (Table 5). These results confirm the data previously obtained for this plant (7).

3. Agricultural implications

The highest estrogenic activity recorded for red clover in the present experiments was about 35 mcgm. per pound of dry matter from second-year growth harvested on May 25, 1956. A 1000-pound grazing animal could be expected to consume about 25 pounds of red clover dry matter per day (22). This would, assuming no loss of active substances in the rumen, lead to a total consumption of 900 mcgm. of estrogenic material expressed in terms of D.E.S. This daily intake is approximately one-tenth that at present recommended for the enhancement of rate of gain in fattening cattle. The effects, if any, of this level of intake of red clover estrogens on the grazing animal cannot be predicted from present information.

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A COMPARISON OF FEEDLOT PERFORMANCE AND CARCASS CHARACTERISTICS OF CHARBRAY x HEREFORD WITH HEREFORD STEERS[1]

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ABSTRACT

Bulls of Charbray breeding and Hereford bulls were turned out with a commercial herd of Hereford cows in southwestern Saskatchewan in 1956. It was assumed the cows were bred at random. At weaning in 1957, 25 Charbray x Hereford (crossbred) steers and 25 Hereford steers were selected at random, weighed and removed to a commercial feed lot where they were fed in two groups to a desirable slaughter finish.

Crossbred steers were heavier at weaning, gained more per day on feed and returned a higher hot carcass weight with a greater eye of lean area than Hereford steers. There was no significant difference between groups in dressing percentage, average thickness of rib fat, TDN consumption per pound of liveweight gain, or average muscle fibre diameters of samples taken from *m. longissimus dorsi*. The Hereford group produced a higher proportion of choice carcasses than the Charbray x Hereford group.

INTRODUCTION

Many commercial cattlemen are currently seeking sires that will increase the weaning weight of calves which after a feeding period will yield a carcass of desirable weight (9) without excessive fat. These producers also wish to exploit heterosis as has been done in poultry and corn breeding.

A number of cattlemen in Canada have practised crossbreeding among the British breeds. Experimentally, Shaw and MacEwan (13) demonstrated the advantages of crossbreeding using Aberdeen Angus, Galloway, Hereford and Shorthorn breeds. Using sires of the three more popular British beef breeds in rotation, Knapp, Baker and Clarke (7) found that crossbreds of each generation exceeded Hereford controls in weaning weight, final feedlot weight and average daily gain in the feedlot. Holt (6) upon reviewing 22 published experiments concluded that, when used in cross-breeding programs, the common beef breeds consistently display hybrid vigour in measured production traits.

To capitalize on heterosis, beef animals of even more diverse origin have been crossed with the range Hereford in western Canada. Purebred Brahman do not appear to be adaptable to range conditions in Canada, but Brahman x Hereford, Brahman x Aberdeen Angus and Brahman x Shorthorn crossbreds have outweighed Herefords at birth and weaning, and at 2.5 years of age were 90 to 160 pounds heavier than Herefords (11). Crossbreds dressed 3 to 4 per cent higher and graded higher because of finish than Herefords (11). A further diversification of genetic origin in animals for crossbreeding purposes resulted from the introduction of Charolais and Charbray bulls into western Canada. This paper presents a comparison of feedlot performance and carcass characteristics of Charbray x Hereford crossbreds with Hereford steers.

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MATERIALS AND METHODS

The data used in this study were from beef cattle bred by the Cypress Cattle Company of Maple Creek, Saskatchewan. The cow herd was representative of range Herefords grazing the southern grasslands of the Canadian prairie region. Eight bulls of Charbray (Charolais x Brahman) breeding and Hereford bulls were turned out with the cow herd during the breeding season of 1956. It was assumed that all bulls bred randomly.

At weaning during the autumn of 1957, 25 Charbray x Hereford and 25 Hereford steers were selected at random from a group of 800 to 900 calves, weighed as groups, moved to a commercial feedlot and placed on a fattening ration. The ration, made up of hay and concentrates, was balanced to meet N.R.C. recommendations (10). The crossbred and Hereford steers were full fed as groups in adjacent pens; animals had access to water at all times. The trail, which commenced in November 1957, and terminated in July 1958, embraced a feeding period of 242 days. One animal from each group was lost due to urinary calculi. In addition, two crossbreds were removed because of an accidental injury to one and a contagious disease in the other. When it was judged that both groups of steers were sufficiently finished to return an average carcass grade of low choice, all steers in both groups were slaughtered at a commercial abattoir. Both groups were fasted for 24 hours and each animal was weighed prior to slaughter to determine a shrunk liveweight. After slaughter, the hot carcass of each animal was weighed and dressing percentage was determined using these two weights. Grading was done by a representative of the Canada Department of Agriculture Marketing Service in accordance with current regulations. After grading, carcasses were quartered, a photographic grid was placed over the rib section and photographs were taken following the general system outlined by Schoonover and Stratton (12). Unfortunately one canister of film was accidentally exposed; hence eye of lean and fat cover measurements were available from only 15 crossbred carcasses (Tables 2 and 3).

Eye of lean area was determined using a planimeter, while fullness of meat and average depth of fat cover over the eye muscle were measured according to Kneebone *et al.* (8). The maximum depth of lean meat at the rib and greatest depth of eye muscle were measured according to Yeates' method (15)

Muscle tissue cores were removed from *m. longissimus dorsi*, preserved and measured by methods described previously*, (14).

RESULTS AND DISCUSSIONS

The effect of breed of sire on the weaning weight of calves is illustrated in Table 1. The average weaning weight of Charbray-sired steers exceeded that of their Hereford counterparts by approximately 71 pounds or 19 per cent. These results confirm the general findings of others (6, 7, 13) that

* MacDonald, M. A., and S. B. Slen. The effect of estradiol and testosterone injections and thyroidectomy on muscle fibre diametes and live weight gain in yearling sheep. *Submitted for publication.*

TABLE I.—AVERAGE WEANING WEIGHT, LIVEWEIGHT GAIN AND EFFICIENCY OF GAIN OF STEERS ON FEED

	Hereford steers	Charbray × Hereford steers
	pounds	pounds
Weaning weight	370	440
Initial weight on feed	354	420
Shrunk weight at slaughter	815	946
Liveweight gain	460	526
Feeding period (days)	242	242
Daily gain	1.9	2.2
Feed consumed per head: Hay	1080	1176
Concentrates	3146	3600
Estimated TDN consumer per head	2900	3288
Estimated TDN per lb. of liveweight gain	6.3	6.3

weaning weights of crossbreds exceed those of purebreds. During transportation from the weaning site to the feedlot, Hereford steers lost 15.5 pounds compared with an average loss of 20.0 pounds for the crossbreds.

In the feedlot no marked difference between groups was evident regarding the ease with which animals were brought up to full feed. Throughout the trial the ratio of pounds of hay to concentrates consumed was approximately 1 to 3 and is characteristic of steer feeding practice in that area. Average liveweight gains and efficiency of gain of the crossbred group approximated the performance expected of fattening calves finished as short yearlings (10). The Hereford group consumed less TDN and gained less liveweight per day than the crossbred group. TDN values were derived using NRC standards (10). However, there was no difference between groups in the efficiency of conversion of TDN to pounds of liveweight gain (Table 1). Because animals were fed in groups, it was necessary to assume that animals which were removed from both groups because of urinary calculi, disease or injury, consumed average amounts and proportions of feedstuffs while in the feedlot. Calculated efficiencies are based on that assumption.

Crossbred steers went on feed at heavier liveweights, gained more and subsequently finished at heavier liveweights at the end of the 242-day feeding period than steers of the Hereford group; the difference being 65.6, 66 and 131 pounds respectively for the three weight categories compared (Table I). Final shrunk liveweights for the Charbray x Hereford group ranged from 820 to 1260 pounds while those of the Hereford group ranged from 600 to 970 pounds.

The hot carcass weights of crossbred steers averaged 557.3 pounds compared to 484.5 pounds for the Hereford group. The average difference of 72.8 pounds per carcass in favour of the crossbreds was significant ($p < .01$). Hereford steers returned a slightly higher dressing percentage than crossbred steers but the difference was non-significant (Table 2.)

The eye of lean area was significantly ($p < .01$) larger in the Charbray x Hereford crossbred steers than in the Hereford steers, the areas being 9.92 and 8.49 square inches respectively (Table 2). Eye of lean area, per hundred pounds of hot carcass, was greater in crossbred than in Hereford steers but the difference was not significant.

TABLE 2.—AVERAGE SLAUGHTER DATA FROM CHARBRAY × HEREFORD CROSSBRED AND HEREFORD STEERS

	Hereford steers	Charbray × Hereford steers
Shrunk liveweight (lb.)	8.15	948**
Hot carcass weight (lb.)	484.5	557.3**
Dressing percentage	59.4	58.9
Eye of lean area (in.)	8.49	9.92*
Maximum depth of lean meat (in.)	2.44	3.47**
Greatest depth of eye muscle (in.)	1.98	2.17**
Fullness of meat (in.)	3.46	3.56
Muscle fibre diameter (microns)	47.9	45.9
Fat cover over the eye muscle (in.)	0.9	0.6

*Significantly greater than the Hereford group ($p<.05$)
**Significantly greater than the Hereford group ($p<.01$)

Average rib fat cover over *m. longissimus dorsi* averaged 0.9 inches in the Hereford group steers compared to 0.6 inches in those of the crossbred group. However, it was apparent that there was a considerably greater area of lean meat compared with fat cover over the eye muscle area in crossbred carcasses than in the Hereford carcasses making the rib cuts more desirable to consumers by current standards of preference in Canada.

In spite of the greater area in the eye of lean of steers in the crossbred group, muscle fibre diameters from *m. longissimus dorsi* were smaller in crossbred than in Hereford steers. However, the difference was not significant (Table 2). These results would indicate that in spite of the larger eye of lean area, the muscle tissue of the crossbred steers was no coarser than that of Hereford steers.

The correlations of some carcass measurements with other measurements within crossbred and Hereford groups presented in Table 3 reveal interesting results. As expected, hot carcass weight and shrunk liveweights were significantly ($p<.01$) correlated within both Charbray x Hereford and Hereford groups. However, a negative correlation ($p<01$) was obtained between dressing percentage and liveweight within the crossbred group. Since dressing percentage is related to degree of fill and percentage of fat in the carcass (3, 4), since all the animals in this trial were on the same feeding regime prior to slaughter and since alimentary tract increases to a power of less than unity with growth (2), it is logical to conclude that heavy animals were proportionally less fat than lighter animals within the crossbred group. This conclusion was not confirmed by the correlation of depth of fat cover with liveweight in the crossbred group since the correlation, while negative, was not significant. The correlation of dressing percentage with depth of fat cover over the eye muscle was positive ($p< .01$) and is in accordance with results expected (3,4).

Correlations of muscle fibre diameters with maximum depth of lean meat and fullness of meat were significant within the crossbred group only (Table 3). The latter two measurements are quite similar, so it was expected

TABLE 3.—GROSS CORRELATIONS OF SOME CARCASS MEASUREMENTS WITH OTHER MEASUREMENTS WITHIN CROSSBRED AND HEREFORD GROUPS

		Hot carcass weight	Dressing %	Eye muscle area	Depth of fat cover over eye muscle	Maximum depth of lean meat	Greatest depth of eye muscle	Fullness of meat	Muscle fibre diameters
Liveweight	H[1]	.913**	.007	.226	.464	.026	.037	.165	—.019
	X[2]	.854**	—.626**	.648**	—.050	.478	.156	.187	.017
Hot carcass weight	H		.474**	.338	.599**	—.006	.019	.193	—.259
	X		.339	.792**	.000	.366	.273	.258	—.059
Dressing per cent	H			.235	.505*	—.060	—.015	.098	.000
	X			.396	—.061	.113	.289	.188	—.244
Eye muscle area	H				.018	.115	.316	—.215	.003
	X				—.136	.598*	.751**	.551	.128
Depth of fat cover over the eye muscle	H					—.377	.062	.145	—.036
	X					—.182	—.270	—.132	—.016
Maximum depth of lean meat	H						.458*	.356	.012
	X						.789**	.848**	.537**
Greatest depth of eye muscle	H							.504*	.012
	X							.827**	.376
Fullness of meat	H								—.014
	X								.512*

[1] H—Hereford group
[2] X—Charbray × Hereford group

*p<.05
**p<.01

TABLE 4.—SUMMARY OF CARCASS GRADING OF HEREFORD AND CHARBRAY × HEREFORD STEERS

Grade	Description	Herefords		Charbray × Herefords	
		%	No. of Animals	%	No. of Animals
Choice		83	20	64	14
Good	Lacked finish	8	2	18	4
	Lacked conformation			9	2
	Lacked conformation and finish			9	2
Standard	Lacked conformation and finish	4	1		
D_1	Lacked conformation and finish	4	1		

that the correlations should also be quite similar. It was not unexpected to find correlations of various measurements involving *m. longissimus dorsi* to be significantly correlated with each other.

Results of carcass grading appear in Table 4. Carcasses which graded below choice were grouped to indicate the reasons for having a lower grade. It was evident that Hereford carcasses reached a higher standard of finish and were of more desirable conformation than crossbred carcasses. None of the carcasses was excessively finished and one Hereford carcass was decidedly underfinished as a result of an injury during the feeding period. Variation within the Hereford group particularly was such that, had all animals of choice carcass conformation been retained until all were fattened sufficiently well to reach choice grade, some steers would have been excessively fat. By Canadian Marketing Service standards an animal must be of both choice conformation and choice finish to be graded a choice carcass. Eighteen per cent of the crossbreds lacked choice conformation. The price differential between choice and good grade carcasses was sufficiently small that net profit per carcass favoured the crossbred groups.

Results of this experiment indicate that Charbray bulls, when mated to range Hereford cows, produce calves which are heavier at weaning, yield greater feedlot gains with equal efficiency and acceptable carcass conformation and finish compared with Hereford steers. It may be concluded that Charbrays are suitable sires with which to cross on Hereford cows to increase beef steer size and beef production in the southern prairie region of Canada.

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THE EFFECT OF ROUTE OF ADMINISTRATION UPON GROWTH RESPONSE TO PENICILLIN BY TURKEY POULTS

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ABSTRACT

Turkey poults were used to study the response to penicillin when administered in the feed, injected intramuscularly and injected intraperitoneally. A comparable growth response was obtained using all three routes of administration.

Contents of the small intestine were assayed for penicillin by the conventional microbiological method. After intramuscular injection, the level of penicillin in the gut rose sharply to nine units per gram of wet contents, but fell off rapidly in a few hours. Subsequently it remained at one to two units per gram of wet contents for several days. This latter amount was approximately the concentration found when 7 p.p.m. procaine penicillin was included in the ration.

Penicillin reduced lactobacilli counts in the small intestine whichever route of administration was used. Coliform counts were increased when penicillin was added to the feed, but not when it was injected.

INTRODUCTION

The existence of a growth response in chickens and turkeys to antibiotics, either added to the feed or injected, was established some years ago (4, 7). However, the means by which this growth response is effected is still unknown.

The work of Anderson *et al.* (1) and Cook *et al.* (2) on the influence of penicillin upon levels of coliforms and lactobacilli in the gut and on the effect of coliforms on growth rate suggests that the growth response ordinarily obtained with antibiotics is due at least in part to effects on the gut flora. Experiments reported by Wiseman *et al.* (10) and Murray and Campbell (8) suggest that the growth-promoting ability of antibiotics may be due to a reduction in the competition between the gut flora and the host for an essential metabolite or metabolites.

If it is correct that orally-administered antibiotics stimulate growth by acting on the intestinal microflora, then injected antibiotics may operate in the same manner and, if so, they must reach the intestines in concentrations comparable to those obtained when the antibiotic is added to the feed. Although Haverman and Sharpenseel (6) have studied the excretion of penicillin fed in the diet, the appearance in the intestine of an injected dose of antibiotic has not been investigated.

The present work was designed (a) to compare the growth response obtained when penicillin was fed in the diet, injected intramuscularly and injected intraperitoneally; (b) to determine the effect of penicillin administered by these three routes on lactobacilli and coliform counts in the intestine, and (c) to measure the rate of appearance in the intestine of intramuscularly-injected penicillin.

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MATERIALS AND METHODS

The growth trial was conducted with day-old Broad Breasted Bronze turkey poults. They were randomized into pens in battery brooders to provide the following treatment groups:

(i) Control—no penicillin
(ii) Procaine penicillin in starter diet at the rate of 7 p.p.m.
(iii) Intramuscular injection once weekly, 60,000 I. U. procaine penicillin
(iv) Intramuscular injection twice weekly, 30,000 I.U. procaine penicillin
(v) Intraperitoneal injection once weekly, 60,000 I.U. procaine penicillin
(vi) Intraperitoneal injection twice weekly, 30,000 I.U. procaine penicillin.

The basal diet was a 28 per cent protein poult starter currently in use at this laboratory. The antibiotic used for injection was a veterinary grade oil base preparation containing 300,000 International Units of penicillin G procaine per cc.* The breast muscle was the site chosen for intramuscular injection, and a site near the posterior end of the sternum was chosen for intraperitoneal injection. Each treatment was replicated three times with 16 poults of mixed sex per sub-group. The experiment was terminated when the poults were 4 weeks of age.

At the conclusion of the growth trial, three birds were selected at random from each treatment for bacteriological investigation. That portion of the small intestine which lies between the distal end of the duodenum and the junction of the ceca and intestine was separated from the rest of the viscera and its contents flushed out. Contents of the large intestine were isolated by a similar procedure. Lactobacilli were determined in the intestinal contents by use of Rogosa's (9) medium specific for lactobacilli. Coliforms were determined by the dilution count method of Hajna and Perry (5).

*"Ayercillin", manufactured by Ayerst, McKenna & Harrison Ltd., Montreal, Que.

TABLE 1—GROWTH RESPONSE OF TURKEY POULTS TO PENICILLIN INJECTED INTRAMUSCULARLY AND INTRAPERITONEALLY

Treatment	Body weight at 4 weeks	
	Males	Females
	gm.	gm.
Control—no penicillin	546	487
Penicillin fed	646	535
Intramuscular penicillin once weekly	605	542
Intramuscular penicillin twice weekly	660	579
Intraperitoneal penicillin once weekly	574	528
Intraperitoneal penicillin twice weekly	615	524
L.S.D. ($p<0.05$)	35	31

The rate at which injected penicillin appears in the small intestine was measured on a group of 4-weeks-old poults which had been reared on a penicillin-free diet. A number of the birds were injected intramuscularly with 60,000 I.U. of procaine penicillin. At various intervals after injection two birds, which had received intramuscular penicillin, and one which had not, were killed and their intestinal contents collected as described above. Intestinal material thus obtained was immediately extracted for a period of 5 minutes with 95 per cent methanol. The resulting slurry was centrifuged and dilutions of the supernatant were used for assay of penicillin by the conventional pad-plate method employing *Micrococcus pyogenes* var. *aureus* as the assay organism. Proof of identity of the inhibitory substance was established by treating a duplicate set of pads in each assay with penicillinase.

RESULTS AND DISCUSSION

A growth response to penicillin was obtained in both males and females and with all three routes of administration (Table 1). Treatment effects were shown to be significant by analysis of variance. Intramuscular injection was more effective than intraperitoneal and in general twice-weekly injections were more effective than once-weekly. It is likely that differences in the effectiveness of various methods of administration are associated with their ability to maintain an adequate and constant level of antibiotic in the intestine.

TABLE 2.—BACTERIAL COUNTS FROM THE INTESTINES OF TURKEY POULTS; LOG_{10} OF NUMBERS PER GRAM WET WEIGHT

Treatment	Small intestine		Large intestine
	Lactobacilli	Coliforms	Lactobacilli
No penicillin	6.23	6.88	7.53
Penicillin fed	4.65	8.11	6.17
Intramuscular once weekly	5.57	7.13	5.82
Intramuscular twice weekly	4.01	6.65	4.17
Intraperitoneal once weekly	5.95	6.47	6.07
Intraperitoneal twice weekly	3.93	6.69	5.39

TABLE 3.—PENICILLIN RECOVERY FROM THE SMALL INTESTINE OF TURKEY POULTS AFTER A SINGLE INTRAMUSCULAR INJECTION OF PENICILLIN

Time after injection	Units per gram wet contents*	Units in intestine*
1 hour	11.1	51
3 hours	1.6	19
6 hours	1.4	19
1 day	0.7	12
2 days	0.7	9
4 days	0.2	6
7 days	0.3	9

* Means of duplicates

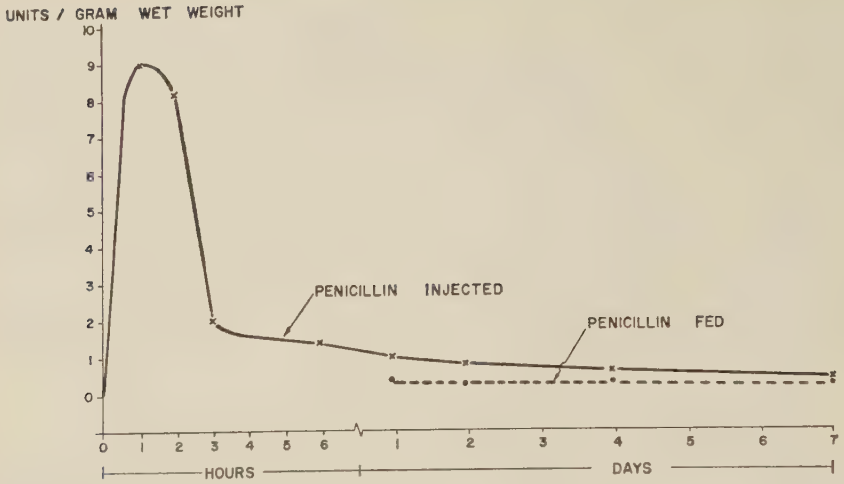

FIGURE 1. Levels of penicillin in the small intestine of turkey poults after oral and intramuscular administration.

The effects of penicillin on lactobacilli and coliform counts in the intestines are shown in Table 2. Twice-weekly injections by either the intramuscular or intraperitoneal route were more effective in reducing lactobacilli counts than a weekly injection. However, penicillin reduced lactobacilli counts whatever the method of administration. On the other hand, coliform counts were increased when penicillin was fed, which agrees with the results of numerous other workers (1, 2, 10) but were not increased when the penicillin was injected. The reason for this failure of injected penicillin to alter coliform numbers is not known.

The rates of appearance and subsequent disappearance of penicillin in the small intestine following a single intramuscular injection of 60,000 I.U. of penicillin are shown in Table 3 and Figure 1. The level of antibiotic in the gut rose to about 9 units per gram of wet contents 1 hour after injection but declined sharply after 3 hours. Thereafter it decreased slowly. At the conclusion of the experiment, 7 days after injection, a small but measurable activity still persisted. The two curves in Figure 1 show a close relationship between penicillin concentration in the small intestine after feeding 7 p.p.m. of the drug and the concentration which was maintained from the first to the seventh day after injection.

The authors consider the results of the experiments to indicate that the mechanism of growth response to injected penicillin and penicillin administered in the feed is similar, in so far as sufficient penicillin from injection reaches the gut to cause typical suppression of lactobacilli.

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EFFECTS OF LEVELS OF DRIED APPLE POMACE IN SWINE RATIONS ON GROWTH RATE, FEED EFFICIENCY, CARCASS QUALITY AND SIZE OF CERTAIN ORGANS[1]

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ABSTRACT

Two experiments, involving 84 Yorkshire feeder pigs, were conducted to test rations containing various levels of dried apple pomace. In the first experiment dried apple pomace was used at levels of 0,10,20, and 30 per cent by weight of the ration and in the second experiment at 0,20, and 40 per cent.

At pomace levels up to 20 per cent no significant change occurred in daily gain, dressing percentage, carcass quality or weight of heart, liver, spleen or small intestine, in either experiment. In the second experiment, there was significantly greater feed consumption per unit of gain, heavier large intestine and lighter stomach at the 20 per cent pomace level. Increasing the pomace level to 40 per cent resulted in significantly slower growth, lower dressing percentage, greater feed consumption per unit gain, leaner carcass, heavier liver, lighter stomach, and heavier large intestine.

In the second experiment, an estimated difference of 2-3 per cent crude protein in the two rations fed at each pomace level had no significant effect on any of the characteristics or organs studied.

INTRODUCTION

Dried apple pomace, a by-product of apple juice extraction, is a high-fibre, low-protein material. Morrison (5) reported studies on its use in rations for cattle, but the literature does not give any reports on studies of its use in swine rations.

The experiments reported in this paper were designed to study the effect of swine rations containing various levels of dried apple pomace on growth rate, feed efficiency, carcass quality, and organ size.

MATERIALS AND METHODS

Two experiments to test various levels of dried apple pomace in rations for growing-fattening pigs were conducted at the Experimental Farm, Agassiz, British Columbia. Experiment I was conducted in the winter, 1955-56, and Experiment II in the summer, 1956.

Pigs used in both experiments were purebred Yorkshires, bred at Agassiz. In Experiment I, only barrows were used. In Experiment II, both gilts and barrows were used. Corrections for sex differences were made prior to further statistical analysis.

All pigs were put on test rations at 50 lb. live weight. All were individually self-fed in drylot and had free access to water.

Pigs were taken off test for slaughter as they reached 200 $\pm$ 10 lb. live weight. They were taken off feed and water 24 hours before slaughtering and shrunk live weights were taken after 21 hours.

[1] Joint contribution from the Research Branch, Canada Department of Agriculture, Experimental Farm, Agassiz, B.C., and Division of Animal Science, University of British Columbia, Vancouver, B.C.
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TABLE 1.—PERCENTAGE COMPOSITION OF GROWING AND FINISHING RATIONS CONTAINING VARIOUS LEVELS OF DRIED APPLE POMACE FED IN EXPERIMENT I[1]

Ingredients	0% Pomace		10% Pomace		20% Pomace		30% Pomace	
	Growing[2]	Finishing[3]	Growing	Finishing	Growing	Finishing	Growing	Finishing
	%	%	%	%	%	%	%	%
Apple pomace	—	—	10	10	20	20	30	30
Barley	54	60	51	58	50	55	50	55
Oats	30	29	20	20	10	10	—	—
Meat scrap	8	4	9	5	10	7	10	7
Soybean oilmeal	5	4	7	4	7	5	7	5
Linseed oilmeal	2	2	2	2	2	2	2	2
Salt	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Limestone	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Crude protein[4]	15.3	13.4	15.8	13.2	15.6	13.7	15.0	13.1
Crude fibre[4]	6.8	6.9	7.3	7.4	7.8	7.9	8.3	8.4

[1] All rations for the growing period of 50-110 lb. live weight contained dry Vitamin A supplement at the rate of 650 I.U./lb.
[2] 50-110 lb. live weight
[3] 110-200 lb. live weight
[4] Estimated from values given by Morrison (5)

TABLE 2.—PERCENTAGE COMPOSITION OF GROWING AND FINISHING RATIONS CONTAINING VARIOUS LEVELS OF DRIED APPLE POMACE AND PROTEIN AS FED IN EXPERIMENT II[1]

Ingredients	0% Pomace			20% Pomace			40% Pomace		
	Protein 15-13%		Protein 18-15%[5]	Protein 15-13%		Protein 18-15%[5]	Protein 15-13%		Protein 18-15%[5]
	Growing[2]	Finishing[3]	Growing	Growing	Finishing	Growing	Growing	Finishing	Growing
	%	%	%	%	%	%	%	%	%
Apple pomace	—	—	—	20	20	20	40	40	40
Barley	55	60	50	52	55	40	39	44	31
Oats	30	30	27	10	12	14	—	—	—
Meat scrap	8	4	12	9	7	16	12	9	18
Soybean oilmeal	6	5	10	8	5	9	8	6	10
Salt	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Limestone	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Crude protein[4]	15.1	13.2	18.1	15.0	13.2	18.2	15.0	13.1	18.1
Crude fibre[4]	6.8	6.9	6.5	7.7	7.9	7.7	9.2	9.3	9.0

[1] All rations for the growing period 50-110 lb. live weight contained dry Vitamin A supplement at the rate of 650 I.U./lb.
[2] 50-110 lb. live weight
[3] 110-200 lb. live weight
[4] Estimated from values given by Morrison (5)
[5] Protein 18-15% Finishing is the same as Protein 15-13% Growing and is, therefore, not shown on the table.

In Experiment I, levels of 0,10,20 and 30 per cent pomace by weight of the rations were studied. All rations contained 15-16 per cent crude protein for the growing period from 50 to 110 lb. live weight and 13-14 per cent for the finishing period from 110 to 220 lb. live weight. Table 1 gives the components of the rations. The dried apple pomace used in both experiments contained a maximum of 4 per cent crude protein and 16 per cent crude fibre. Two replicates were used with 12 pigs per replicate (3 pigs per treatment). Allotment was at random.

In Experiment II, levels of 0,20, and 40 per cent pomace by weight of the rations were studied, each at two levels of protein. These were: 15-13 per cent (15-16 per cent crude protein from 50 to 110 lb.; 13-14 per cent from 110 lb. to slaughter) and 18-15 per cent (18-19 per cent crude protein from 50 to 110 lb.; 15-16 per cent from 110 lb. to slaughter). Table 2 gives components of the rations used. Two replicates were used, with 30 pigs per replicate (5 pigs per treatment). Allotment was at random.

After slaughter the heart, liver, spleen, stomach, small intestine, and large intestine were cleaned of extraneous tissue, emptied of any contents, and weighed. The large intestine included the caecum and rectum.

The carcasses, including kidneys, leaf fat, head and feet, were weighed while hot and again after chilling for approximately 84 hours. The chilled carcasses were cut into commercial cuts by experienced meat-cutters.

In order to avoid any bias that might be introduced by differences in carcass weights, the following percentages were used:—

1. *Lean cuts*—shoulder, ham, and loin each as a percentage, after trimming, of the cold carcass weight minus head, feet, and kidneys.
2. *Fat cuts*—leaf fat plus the fat trim from the shoulder, loin, ham, and belly as a percentage of the cold carcass minus head, feet, and kidneys.
3. *Belly*—trimmed belly as a percentage of the cold carcass minus head, feet, and kidneys.
4. *Organs*—each as a percentage of the hot carcass weight.
5. *Digestive tract*—each section as a percentage of hot carcass weight.

Dressing percentage was the hot carcass weight expressed as a percentage of the shrunk weight off test. Daily gain was calculated as the difference between live weight of animals when placed on test and shrunk live weight when taken off test divided by the total days on test.

Feed efficiency was calculated on the basis of feed consumed per 100 lb. body weight gain.

Analysis of variance was used to test differences between treatment means at the 5 and 1 per cent significance levels.

RESULTS AND DISCUSSION

Tables 3 and 4 summarize results from the two experiments.

Effect of Pomace Level

(*a*) Daily gain and feed efficiency

In Experiment I, rate of gain was not affected by pomace levels. In Experiment II, rate of gain was not affected by 20 per cent pomace. There

TABLE 3.—THE AVERAGE DAILY GAIN, FEED CONSUMPTION, FEED EFFICIENCY, DRESSING PERCENTAGE AND CARCASS DATA FROM PIGS FED RATIONS CONTAINING VARIOUS LEVELS OF DRIED APPLE POMACE AND PROTEIN

Treatment	Number of pigs	Weight on test	Shrunk weight off test	Daily gain	Feed consumption		Dressing percentage	Shoulder	Loin	Ham	Fat cuts	Belly
					per day	per 100 lb. body gain						
		lb.	lb.	lb	lb.	lb.	%	%	%	%	%	%
Experiment I												
0% Pomace	6	50.7	190	1.52	5.9	391	81.3	21.4	15.9	21.5	26.8	14.5
10% Pomace	6	50.8	192	1.49	5.8	391	80.8	21.9	16.2	21.3	26.7	13.9
20% Pomace	6	51.0	188	1.51	6.2	408	81.2	21.7	15.8	21.5	26.5	14.6
30% Pomace	6	52.0	189	1.58	6.6	415	80.1	21.3	15.3	21.4	28.2	14.0
Experiment II												
0% Pomace	20	50.6	193	1.36	6.0	441	80.4	22.9	16.5	22.5	24.5	13.5
20% Pomace	20	50.8	191	1.36	6.4	468[1]	79.8	23.1	16.9	22.5	24.0	13.5
40% Pomace	20	50.9	190	1.27[1]	6.3	505[1]	78.9[1]	23.4	17.3[1]	23.4[1]	22.5[1]	13.4
Protein 15-13%	30	50.8	191	1.33	6.2	469	79.9	23.0	16.8	22.7	23.8	13.4
Protein 18-15%	30	50.8	191	1.34	6.3	475	79.6	23.3	17.0	22.9	23.6	13.5

[1] Significantly different from the 0% Pomace ration at p = 0.05 or less

was, however, a significant reduction in rate of gain at the 40 per cent pomace level.

Feed efficiency decreased significantly as pomace levels increased in Experiment II and there was a similar trend, not significant statistically, in Experiment I.

The growth rate reduction on the high pomace rations may indicate an influence of the increased fibre content (Tables 1, 2) of these rations. Similar results were obtained by Bohman *et al.* (1) with high fibre rations containing alfalfa as the major source of fibre.

(*b*) Dressing percentage

There was a significant reduction in dressing percentage at the 40 per cent pomace level. Studies by Coey and Robinson (2) and Bohman *et al.* (1) indicate that increased digestive tract size is a factor in decreasing dressing percentages on high fibre rations. The increased large intestine weight at the 40 per cent pomace level may be a contributing factor in lowering the dressing percentage in this study. That this is not the only factor affecting the dressing percentage may be indicated by the lack of a decrease in dressing percentage at 20 per cent pomace, despite a significant increase in the large intestine weight. The fact that the pigs on 40 per cent pomace were leaner could also be a contributing factor in reducing dressing percentage since leaner pigs usually have lower dressing percentages.

(*c*) Carcass quality

In Experiment I, there was no significant effect of pomace level on any of the carcass cuts. In Experiment II, there was a significant increase in percentage of loin and ham and a significant decrease in percentage of total fat cuts at the 40 per cent pomace level. This increase in carcass lean with increased pomace level may be a result of increased ration bulk with resulting reduction in the useful nutrient intake. This would have the same

TABLE 4.—AVERAGE OF ORGAN WEIGHTS AS A PERCENTAGE OF HOT CARCASS WEIGHTS FROM PIGS FED RATIONS CONTAINING VARIOUS LEVELS OF DRIED APPLE POMACE AND PROTEIN

Treatment	Heart	Liver	Spleen	Stomach	Small intestine	Large intestine
	%	%	%	%	%	%
Experiment I						
0% Pomace	.36	1.92	.16	.88	1.94	1.57
10% Pomace	.36	2.22	.17	.79	1.99	1.70
20% Pomace	.35	1.97	.17	.77	1.99	1.74
30% Pomace	.36	2.12	.17	.81	1.96	2.04
Experiment II						
0% Pomace	.41	2.04	.17	.87	1.69	1.81
20% Pomace	.41	2.08	.16	.76[1]	1.63	2.20[1]
40% Pomace	.43	2.22[1]	.16	.83[1]	1.74	2.41[1]
Protein 15-13%	.42	2.16	.16	.82	1.70	2.15
Protein 18-15%	.41	2.07	.16	.82	1.68	2.14

[1] Significantly different from the 0% Pomace ration at $p = 0.05$ or less.

effect as restricting the feed intake. Increased lean in carcasses of pigs on restricted feed intake has been demonstrated by McMeekan (3) and McMeekan and Hammond (4).

(*d*) Liver

Liver weight was significantly higher only at the 40 per cent pomace level in Experiment II. Walter and Addis (7) observed an increase in liver weight with increased liver activity. It is not possible to determine from the data available whether or not the increased weight of the liver in this study reflects an increase in activity but it exists as one possible explanation.

(*e*) Stomach

In Experiment II, stomach weights were significantly lower at 20 per cent and 40 per cent as compared to the ration with no pomace. In Experiment I, stomach weights for the three pomace rations were also lower than for the no-pomace ration but the differences were not statistically significant.

From the work of Wussow and Weniger (10) and Bohman *et al.* (1), a strong trend to increasing stomach weight with increasing pomace level would be expected as a result of increase in ration bulk. No explanation is apparent for the results reported here which show the opposite effect.

(*f*) Large and small intestine

The large intestine weight increased with increasing pomace content of the ration in both experiments, although differences were significant only in Experiment II. Bohman *et al.* (1) and Wierda (8, 9) obtained similar results with rations containing high levels of fibre. The pig apparently makes some adaptation to high fibre rations through increased large intestine size.

There were no significant differences or trends in small intestine weight in either experiment.

Effect of Protein Level

In Experiment II, there were no significant differences between the protein regimes for any of the characteristics studied. The protein supplied by the 15-13 per cent regime approached closely that recommended by the National Research Council (6) and from the results appears to be adequate for the type of rations used in this study.

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BIOLOGY AND CONTROL OF THE COAST MOLE, *SCAPANUS ORARIUS ORARIUS* TRUE, IN BRITISH COLUMBIA[1]

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ABSTRACT

Coast moles were studied and trapped from 1935 to 1945 at Agassiz, British Columbia. They cause economic damage in the lower Fraser Valley by injuring growing crops and by covering up to 15 per cent of the surface of a field with their hills.

The moles ate almost any arthropod, annelid, or molluscan that they captured, but earthworms comprised 93 per cent of the stomach contents. Adults ate nearly twice their weight in earthworms daily, or 100-150 grams, representing more than 100 worms. The populations of moles apparently varied in proportion to those of the earthworms.

The moles mated from January to early March. The young were born in March or April. Yearling females had two embryos; 2-year-old females had three; and mature females had four. Of 940 trapped during the winters, 45 per cent were over 1, and 6 per cent were over 3 years old. The average weight of mature 74 males was 74.3 $\pm$ 5.6 grams; the average weight of 30 mature females was 69.8 $\pm$ 4.1 grams.

Natural control was ineffective. The disastrous Fraser River flood of 1948 lowered the numbers significantly, but recovery was rapid.

Artificial controls tested included: poisons, caustic irritants, explosives, flooding, earthworm poisons, combinations of chemical fertilizers and irrigations, mechanical and chemical barriers, commercial mole destroyers, poison gases, deterrents, and traps. Only the last two were of value; crude flake naphthalene was a deterrent, and the scissors type was the most effective trap. In heavy infestations as many as three moles per man-hour were trapped. Naphthalene was expensive but protected small plots for up to 6 weeks. For economic control by trapping an area of 300 to 500 acres should be trapped in one season. Smaller areas are quickly reinfested, since the moles travel up to 1 mile.

INTRODUCTION

The control project was initiated in 1934, in an attempt to overcome the rundown condition of many raspberry plantations, in which mole hills and runways were common. As the literature was fragmentary, with a marked lack of exact information on the coast mole, the study was broadened in scope in 1935 to include all phases of the life-history, and was carried on intensively for 10 years.

BIOLOGY

Range

The coast mole, *Scapanus orarius orarius* True,[3] is a true mole of the family Talpidae which ranges in various forms from the humid coastal region of northern California to extreme southern British Columbia west of the Cascade Range. Here it is confined to the drainage basin of the

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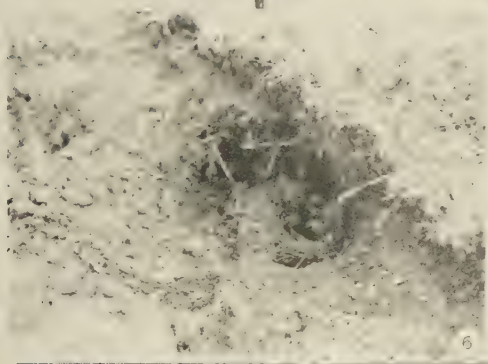
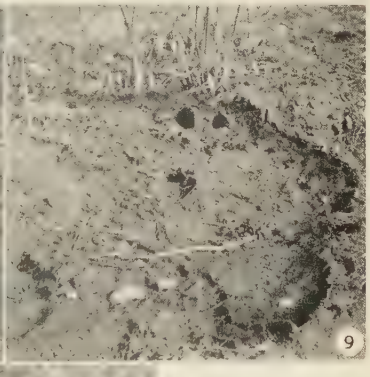
[3] Authority for identification of the mole of the region as *Scapanus orarius orarius* True is I. McT. Cowan, University of British Columbia, Vancouver, B.C.





4. Coast mole (*left and right*) and Townsend mole (*centre*) showing relative sizes.
5. Molehills in a heavily infested pasture.
6. Coast mole nest with young, exposed in plough furrow.

10. English scissor-type traps showing method of capture.

7. Coast moles about 2 weeks old.
8. Surface runs made during one night in summer by young coast moles. Distance between stakes is 100 yards.
9. Open mole runs beneath raspberry canes.

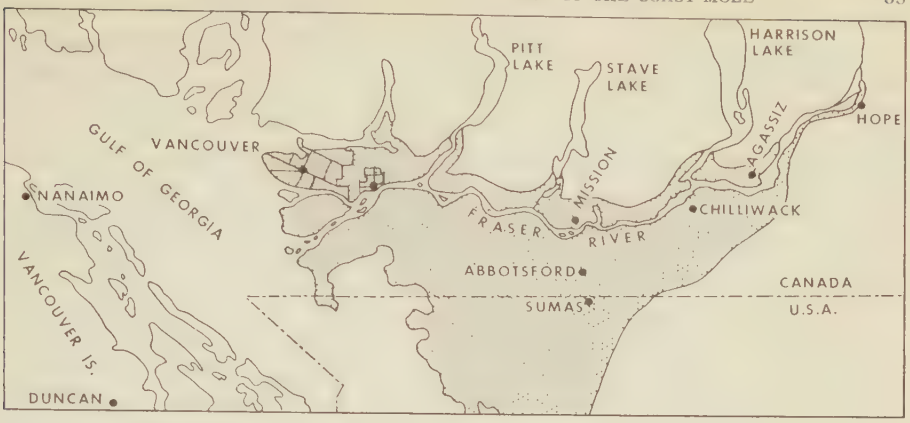


Figure 1. Distribution of the coast mole in British Columbia and the adjacent part of Washington.

lower Fraser River, from Hope westward (Figure 1) 100 miles to the coast, and about 20 miles northward from the United States-Canada border. It does not occur on Vancouver Island, on the islands in the Gulf of Georgia, or on the north shore of Burrard Inlet.

Within this range it is found in almost all types of soils, from the glacial till around Vancouver and the alluvial clay of the Fraser River delta through the bench lands of sands and gravels at Abbotsford and Mission to the river deposits at Sumas, Chilliwack, and Agassiz. It is most abundant in damp alluvial lands long under cultivation and close to the rivers, rapidly becomes less numerous on the heavily timbered hills and mountain slopes, and is rarely found above 1000-feet altitude.

Townsend's mole, *S. townsendi* (Bachman), inhabits an area in British Columbia of about 5 square miles of low-lying black humus land at Sumas, close to the U.S.-Canada border, and is thus of small economic importance in the province. Larger than the coast mole (Figure 4), it makes bigger hills and runways. Its habits in general are similar and the same control measures are applicable.

Methods

Most of the study was made on the Canada Experimental Farm, Agassiz. The area was originally heavily timbered, but is now cleared and devoted to pasture, forage crops, several acres of gardens, and an arboretum. The soil is sandy loam and clay loam, with low ridges of gravelly sand, long in cultivation and heavily manured. It is mostly well drained and normally carries a higher mole population than most other farms in the valley.

At Chilliwack (Figure 1), during the winter of 1937-38, a survey was made of mole and earthworm population in 156 fields, averaging 10 acres each. The worm population was sampled as follows: On a diagonal of each field a shovelful of soil, one spade deep, was turned up every seven to ten paces, and the worms counted. About 30 samples per acre were averaged, and the surface soil type was recorded. The mole population was estimated from the hills since the subterranean habits of moles rule out most observation.

Estimates of populations were confirmed or qualified by trapping. After several years' experience it became possible to estimate the numbers with considerable accuracy.

Data on reproduction were obtained by dissecting trapped specimens and observing the condition of testes, ovaries, or young *in utero*. Food habits were recorded from dissections and by feeding caged specimens experimentally. Tunnelling habits were studied by observing, digging, and mapping during ploughing or excavating, chiefly in pasture fields with heavy sod.

Live moles were obtained by direct capture. Freshly made mole hills were watched and, upon any movement of the soil in a hill, a shovel was plunged beneath the hill and the mole was thrown out on the surface. It was seized quickly and put into a metal container before it had time to burrow.

Cages consisted of enclosures sunk 2 feet into the ground. The sides were made of 6″-x-6″ cedar posts, sheathed with 6 inches of galvanized iron around the top. The bottoms were of half-inch wire netting stapled to the sides. One foot of soil was placed on the netting, in contact with the subsoil. Single moles were kept alive and apparently healthy in these cages for several weeks.

Abundance

Early settlers in the area state that it is within comparatively recent years that moles have multiplied to become pests. The increase is probably due to agricultural activity, which has led to an increase of available food, i.e., in numbers of earthworms in the intensively cultivated and heavily manured fields. The presence of earthworms in the area before the advent of agriculture is a disputed point. If present, they were certainly scarce by comparison with their abundance today.

Within its range in the lower Fraser Valley the coast mole varies greatly in numbers, apparently in proportion to the numbers of earthworms which in turn vary with vegetation, humus, and drainage. During the study, numbers ranged from 4 per acre to 1 per 35 acres. The correlation coefficient between the numbers of moles and earthworms per acre in 157 fields was .82, which was significant at the 5 per cent level.

Some areas in the Fraser River delta have a high water table, few earthworms, and no moles. Land subject to flooding in the central and eastern Fraser Valley, peat bogs, and other high-acid lands are also free from moles. Adjacent bench lands, better drained, carry moderate numbers. Dry sandy ridges in the Valley and the timbered hillsides bordering it carry light populations.

Longevity

The life span is not known accurately from observation of individuals, but was deduced. Records from several hundred moles of weight, fur condition, and number of embryos in gravid females, showed that they fell into four age groups: young of the year (40-60 grams); adults one year old (65-70 grams); adults two years old (71-75 grams); aged adults (>75). Yearling females had two developed embryos, 2-year-olds three, and fully mature females four.

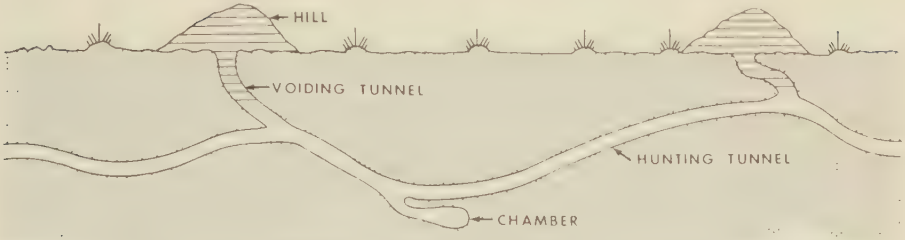


Figure 2. Diagrammatic section of hunting tunnels, chamber, and hills.

Habits

About October, moles that have been living in cultivated fields gradually move to heavily sodded grassland. By late November, pastures are dotted with hills which become more numerous until March (Figure 5). No general freeze-up occurs in the region and the ground is seldom frozen at all before January, and then for a week or so at most.

Between October and March one mole may throw up from 200 to 400 hills, representing the excavations from a network of tunnels up to 500 yards long and 6 to 8 inches below the surface. A network, which is called an "encampment" for want of a better word, may occupy nearly a quarter of an acre. Only one mole occupies each encampment; when the occupant is caught no new hills appear. Runways of an encampment are connected at various depths from 3 to 36 inches (Figure 2). These facts have apparently not previously been recorded. The tunnels are circular, nearly 2 inches in diameter, and every few feet have chambers 4 inches long by 3 inches wide. Sometimes these occur at the junction of two or more tunnels or at the end of a tunnel (Figure 3). Their function is not known.

The hills are nearly uniform, about 1 foot across and 6 inches high, and contain approximatley 160 cubic inches of soil, representing about 6 feet of tunnel. Sometimes larger hills are thrown up, along fence rows and around tree roots.

The moles appear to dig by loosening the soil with the fore claws and pushing it backward in the tunnel already dug. An exit is made at the surface, and the mole, which can run backwards as fast as forwards, moves back over the loosened soil, which it pushes towards and out of the voiding hole. The process is repeated several times to form an average hill. The passage to the voiding hole is almost vertical and often twisted, its length depending on the depth of the horizontal run. It is of the same diameter as the hunting tunnel and is left choked with loose soil. Passages leading to the hills are used by the moles only to void soil. Under deep snow, moles often make surface runs, lined with soil, which are clearly seen when the snow melts.

In towns and built-up areas moles may be present but their activities are often masked. In woodlands and uplands soils, molehills are infrequent, because the moles are able to make tunnels by merely pressing the uncompacted soil aside.

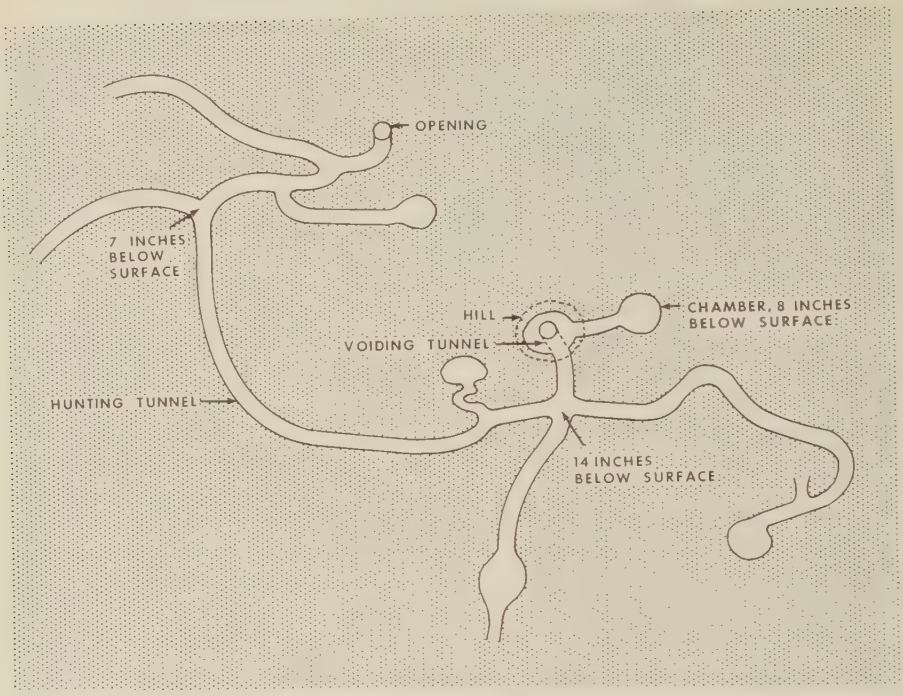


Figure 3. Diagrammatic plan of hunting tunnels, chambers, and hill.

Reproduction

Exact knowledge of the breeding habits of moles is difficult to obtain. Mating was never observed, so that it is not known whether it occurs above or below the soil surface. Probably mating is the only occasion when moles meet without combat. The gestation period was not established.

Although captures indicate that the sexes are about equal in numbers, there were indications that this species may be polygamous. At mating time in January and February, the isolated encampments, normally consisting of a network of tunnels indicated by groups of 50 to 200 hills, are often joined by long runways. These runways are marked by large, widely separated hills. Moles taken at the isolated hills were always males. It is possible that the runways were for communication rather than hunting, and were used by males to visit neighbouring females.

Dissections indicated that mating occurs from January to early March. The testes begin to enlarge in early January, swelling from the size of birdshot to that of white beans. The maximum recorded was 15 x 10 millimeters. Measurements of testes in 60 males in two years from December to May showed a gradual increase until early March, followed by a gradual decrease during late March and April. By May they were again small.

Embryo development was not uniform. Many showed considerable growth by early March, but others reached the same stage a month later. The largest seen were 25 x 15 millimeters, estimated to be not more than

two-thirds grown. No females were captured near the time of parturition, by either trapping or digging; apparently they are very secretive at this time. By May any females caught had given birth to young, teats were developed, and the ovaries were shrunken. No signs of more than one brood a year were found.

The coast mole differs from the European mole in that it does not construct a nesting "fortress" marked by an extra large mound of earth. Nests were found only by accident, not by searching. Several old, unoccupied nests were discovered, usually under tree roots or old buildings or in rough, undisturbed land. All the nests were about 6 inches below the surface, at which depth the soil warmed up in spring fairly readily and the danger from flooding was minimal.

Only two occupied nests were found during the study, on May 22, 1937, at Chilliwack, and on April 19, 1944, at Agassiz. Both were found by farmers while ploughing; both were 6 inches below the surface (Figure 6). The first was near the edge of a pasture that had not been ploughed for many years. No new mole hills or any other indications of mole activity could be seen nearby. The cavity in the clay soil was 8 inches across, and was lined with coarse grass. There were three entrances, from which numerous runways radiated in all directions. In the nest were four young, weighing 40 grams each, more than half the average weight of a yearling. The mother was not seen. The young refused all food and died in 3 days, probably because they were not yet weaned.

The second nest was in a sod field that had not been cultivated for 14 years. It contained two almost naked young (Figure 7), which weighed 13 and 15 grams, were 5.5 centimetres long, and had well-formed feet and tails. They died in a few hours.

On April 11, 1945, a gardener caught three young while he was digging near a hedge at Agassiz. They were captured about one hour apart, suggesting that the nest was nearby. They were placed in cages and given earthworms. Two were dead next morning; the third tried to eat small pieces of worms, but died a day later in a contracted posture. These young were probably still living in the nest with the mother and being fed by her, but not yet weaned or able to digest much solid food. At capture they weighed 32 grams.

After leaving the nest the young forage by moving through the soil 1 or 2 inches beneath the surface. The soil is not excavated and thrown up into hills but is merely formed into a ridge. Up to 300 yards may be made over-night by a single young mole (Figure 8).

Feeding

The coast mole will eat almost any arthropod, annelid, or molluscan that it can capture. It does not feed on carrion, but will consume part of its vanquished opponent after a fight with another mole. No evidence was found of any vegetable matter, frogs, or mice being eaten, although the latter use mole runways freely. Caged moles readily consumed earthworms, slugs, snails, cutworms, beetle grubs, symphylids, chilopods, diplopods, and injured drone bees. Even when starving they would not eat sawfly larvae; certain hairy caterpillars; earthworms that were injured, dried or

tainted; or meat scraps or any dead food. This is not true of other species of moles.

In cage experiments adults ate nearly twice their own weight in earthworms daily, or 100 to 150 grams, representing upwards of 100 worms. The animals died in a contracted posture when fed smaller amounts.

The stomach contents of 108 moles trapped between May and September, 1934, showed the following approximate percentages: earthworms, 93; slugs, 2; larval insects, 2; adult insects (chiefly Hymenoptera), 1; earthworm ova, 1; undetermined, 1.

On occasion the moles may feed freely on insect larvae that can be reached without exposure on the surface. In 1935 at Agassiz, coils of pea vines heavily infested with mature larvae of the pea moth, *Laspeyresia nigricana* Steph., were left for a day or two to dry out on the ground. The soil beneath the coils was riddled with mole runs that opened above ground. At the time the pea moth larvae were leaving the pods in numbers and going into the soil to pupate.

The method of catching and eating earthworms was observed in caged moles. Worms placed on the soil surface up to 2 or 3 inches away were located by scent or movement. The mole approached just under the surface, the snout was barely protruded, and the worm was pulled beneath the surface. The soil was rubbed off by the digits of the fore feet, and the worms were fed into the mouth, chewed rapidly, and swallowed.

Observation of caged moles showed that the search for food must be almost continuous. The animals seldom remained still or asleep for longer than half an hour, and died in a few hours if deprived of food. Tunnelling indicated that the search for food is independent of daylight; hills are thrown up at all hours. To obtain 150 worms per day a mole would have to take one approximately every 10 minutes, which is possible and reasonable, allowing brief periods for sleep.

The number of earthworms consumed must be very large. Four adult moles per acre, which was the maximum recorded, would consume about 219,000 per year. The worm population in old pastures averaged about 6 per square foot, or 261,360 per acre.

Under normal conditions in the lower Fraser Valley, coast moles appear to obtain enough moisture without recourse to surface water. Caged individuals refused water and thrived for several weeks without drinking. Subsoil moisture is always present and may be reached in the relatively soft substratum by deep tunnelling. Many tunnels were found down to $3\frac{1}{2}$ feet, deeper than necessary to avoid frost and in horizons apparently barren of food. The accidental discovery in 1950 of a mole tunnel 7 feet down in compact sand, in the course of sinking a well at Agassiz, adds weight to the assumption that the moles burrow down to subsoil moisture. A mole came out of the tunnel and fell into the well.

Age and Weight

Of 940 moles trapped from November to April between 1935 and 1945, a constant 45 per cent were adults over 1 year old. Six per cent were aged adults over 3 years, based on skin texture and weight. The average weight

in grams of 74 mature males taken during the 10 years, was 74.3 ± 5.6 (range 64-91). The average weight in grams of 30 mature females was 69.8 ± 4.1 (range 61-79). The average weight in grams of 52 adult and yearling males and 53 adults and yearling females, taken from May to September, 1934, was 63.2 ± 8.0 (range 42-77) for males; and 58.1 ± 6.6 (range 40-80) for females. The average length in centimetres of the adult and yearling moles was 16.0 ± .6 (range 14.5-17.6) for males; and 15.7 ± .6 (range 14.3-17.3) for females.

Weight records indicate that during the winter there was abundant food for moles of all ages. The average weights remained constant from November to May.

CONTROL

Economic Status

There is no evidence that moles are beneficial to agriculture. They have been credited with improving the soil by aeration and drainage, and with destroying harmful soil insects. This may have been true in pioneer times and under natural conditions, but is not true in agricultural areas today. Undoubtedly they do consume such pests as cutworms, weevil, larvae, root maggots, wireworms, and white grubs, but not enough to show appreciable benefit.

Surface tunnelling in spring and summer is damaging to young plants, especially when moles move among seedlings where manure and earthworms occur together (Figure 8). Subsurface tunnelling in fall and winter near roots, bulbs, and corms allows meadow mice, *Microtus* spp., to enter and damage these (Figure 9). The most obvious damage results from the hills, which may waste up to 10 per cent or more of an encampment area, besides being ruinous to cutting machinery and sometimes causing erosion (Figure 5). Up to 150 hills in an area of 100 square yards have been counted, each hill presenting close to 1 square foot of bare soil.

There is apparently no market for skins on this continent.

Natural Control

The progeny of a pair during 4 or 5 years of life expectancy would be from 9 to 15. The species is not, therefore, prolific.

Little evidence was seen of important natural control factors. Before the land was settled and cleared, there is little doubt that such predators as hawks, owls, coyotes, weasels, racoons, skunks, foxes and wolves caught moles when opportunity offered. Under present conditions domestic cats and dogs take a small toll, but moles appear to be seldom eaten by them, perhaps because of an unpleasant taste and smell.

Severe and prolonged cold weather in mid-winter with the frost line one foot deep was not observed to lessen the numbers of moles. Flooding from exceptionally heavy rains or from spring run-off causes some mortality only if it occurs when the young are in the nests during April and May. Adult moles swim readily. In the disastrous Fraser River flood of 1948, moles were driven from the fields and were seen swimming to higher land. The estimated annual population on 160 acres at Agassiz for the years 1946-52 was 157 ± 30. In 1948 it was 126. The significant reduction in

numbers after the flood is thought to be due to the destruction of earthworms, rather than to drowning of moles.

Internal and external parasites were observed, but do not appear to have deleterious effects on the host. Up to 137 mites were taken on one mole and up to 48 fleas. Two species of fleas were identified by G. P. Holland, Entomology Division, Canada Department of Agriculture, Ottawa: *Corypsylla ornata* Fox and *Epitedia scapani* (Wagner). No sucking or biting lice were found. Two cases of skin disease were recorded, and were suspected to be of bacterial origin. Two moles were found with numerous cestodes in the duodenum. Two others, showing considerable emaciation, had mucous cysts.

Artificial Control

Only two methods proved effective: trapping with the English scissors trap (Figure 10), and using naphthalene flakes as a temporary repellent. The table below shows by the slow decline in numbers that, to free an area of moles economically, a much larger area than the 160 acres used in this study must be trapped to avoid reinfestation from nearby areas. To judge by observations of reinfestation at Agassiz and Chilliwack, not less than 500 acres should be trapped in one season.

MOLES TRAPPED ON 160 ACRES

1934	*1935*	*1936*	*1937*	*1938*	*1939*
127	348	251	147	98	137
1940	*1941*	*1942*	*1943*	*1944*	*1945*
100	124	70	65	51	17

Each field was trapped until no fresh hills appeared; before the close of the season it was inspected and recent comers trapped. Whenever about four-fifths of the moles in a field had been caught the remainder disappeared. This dispersal may have been connected in some way with the mating season, which coincided with the later part of the trapping season.

The population in any one field varied from year to year according to the cultural treatment, which was a 4-year rotation of hoed crops, grain, hay, and pasture. By the fourth year, earthworms were normally numerous. When a pasture field was ploughed the worm population was greatly reduced together with that of the moles.

Baits were tested in the cages as follows: Worms of 3 to 6 grams were threaded with linen thread, tied around the middle and anchored to a short stick. This was necessary to recover them and see how much had been eaten. Five baited worms per day were placed in the soil under a board, and inspected every few hours. In addition, fresh liver, meat and fish meal were used. Only worms were eaten, and then sparingly and after the moles were starving. Ten materials were tested: red squill (*Urginea maritima* (L.)), fluorine compounds, mercuric chloride, arsenic compounds, *beta*-naphthol, barium carbonate, strychnine, and cincophen. Two moles out of seven died from eating the squill, after being fed 140 worms in 10 days. The other baits were even less effective.

Caustic irritants were tried, such as sodium hydroxide, beta-naphthol, mercuric chloride, sodium fluoride, barium carbonate, and sodium fluosilicate.

These were used as dusts blown into the runways or with an adhesive such as tanglefoot. The moles covered the dusts with earth and were little affected by the poisoned adhesives.

Explosives with various charges were tried in a field of 6 acres of clay loam having an estimated population of seven moles. Charges were fired in the centre of each encampment, and smoke emerged from holes up to 15 feet distant from the charge. The estimated areas of the encampments suggested that the occupants were not over 20 feet away, but no moles were killed.

Artificial flooding has no possibilities under Fraser Valley conditions. Even in gardens and on lawns it is not worth the trouble involved.

Removal of the mole's staple diet by destruction of the earthworms proved to be uneconomic. Mercuric chloride, formaldehyde, lime-sulphur solution, Cooper's Worm Killer,* and derris were all tried, but the maximum mortality of worms was only 40 per cent.

A 4-year test of the effect of combinations of artificial fertilizer and irrigation revealed no significant change in the mole population.

Barriers were either impractical or ineffective. Heavy wire netting, of half-inch mesh and not less than 22 gauge (American Standard) wire, 2 feet above and 3 feet below the surface would be necessary. Lighter wire or larger mesh such as chicken netting can be broken or stretched apart by the powerful front feet. In one instance, fine-mesh copper fly screen on a cage was torn and the mole escaped through the hole. Of chemical barriers only naphthalene flakes proved partly effective, this for a limited time that did not justify the labour involved.

Two commercial mole destroyers were tested in controlled experiments. Both failed to kill any moles because the moles would not eat artificial baits. Most of the remedies current among farmers and gardeners were of European origin and not applicable to the coast mole. Some resulted from confusion between true moles and the phytophagous pocket gophers of inland regions.

Injection of poison gas into runways was not effective under field conditions. Carbon bisulphide, carbon monoxide, cyanide, and chlorine were tested, but in all cases the moles closed off the runways with earth before the gas could take effect.

BHC and crude naphthalene were tested, incorporated in the soil as deterrents. BHC was not effective, but naphthalene was toxic to moles in a confined space. Naphthalene was then field-tested at rates of $2\frac{1}{2}$, 5, and 10 pounds per 100 square feet, spread and raked in by hand on nine plots each of 100 square feet, at various points on the Experimental Farm. Crops of carrots, peas, onions, corn, clover, and mangolds showed no ill effects, but the earthworm population was reduced by about 50 per cent at the two lower rates, and by 75 per cent at the higher rate. No moles entered the plots for 6 weeks, when a young mole was found dead on the surface of a clover plot, having entered by a shallow runway. The check plots were tunnelled freely. The recommended rate is half a pound per

*Cooper, McDougall, & Robertson Ltd., Berkhamsted, Herts, England

square yard, which is too expensive for field use except in small gardens or nursery beds.

Five types of traps were tested: pit, barrel, choker-loop, harpoon, and scissors. The last named (Figure 10) was most suitable and effective against the coast mole. It is cheap, is easy to set, and does not get out of order.

The trapping season is from November to late March, when the moles are confined to limited areas in sod land. With one or two traps in each encampment, about 20-24 traps can be examined or reset by one man in about one hour. The figures for 1936, which are typical, are: In a 12-acre field, 27 moles were caught in 10 man-hours; in an 18-acre field, 21 in 6 man-hours; and in an 8-acre field, 15 in 6 man-hours; these average just under three moles per man-hour.

Traps should be visited every second day. When a mole is caught the trap should be reset elsewhere. It is not necessary to wear gloves or to disinfect the traps; the animals appear to be very unwary.

ACKNOWLEDGEMENTS

The author has pleasure in acknowledging valuable assistance from: the late W. J. Riley, Vancouver, B. C., in feeding experiments, stomach analyses and general help; the late D. G. Gillespie, in testing poison baits; H. G. Fulton, Officer-in-Charge, Entomology Laboratory, Chilliwack, B. C., in general help and especially for the population survey near Chilliwack; and H. R. MacCarthy, Officer-in-Charge, Crop Insect Section, Entomology Laboratory, Vancouver, B.C., in revising the manuscript.

THE VALUE OF SUNFLOWER SEED OIL MEAL AS A PROTEIN SUPPLEMENT FOR LAYING HENS[1]

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ABSTRACT

Two experiments, involving 324 pullets confined to individual cages and 630 pullets in floor pens, were conducted to determine the value of commercial sunflower seed oil meal as the major protein supplement in laying rations.

In rations containing 2.0 or 2.5 per cent fish meal, the complete replacement of other supplementary protein sources with sunflower seed oil meal had no influence on mortality, egg production, egg weight or body weight maintenance. However, feed consumption tended to be higher when meat meal was replaced by its protein equivalent of sunflower seed oil meal, and by an equivalent amount of mineral supplement.

INTRODUCTION

Published information on the value of commercial sunflower seed oil meal as a protein supplement in laying rations is very limited. Tabakoff (3) reported that, in spite of lower production, it was economically sound, under Bulgarian conditions, to replace 20 per cent meat meal with 20 per cent sunflower meal in laying mash being fed with grain. However, he compared meat meal and sunflower meal on a pound-for-pound rather than a protein equivalent basis, and the lower production observed with sunflower meal may have been partially due to the lower protein of the sunflower meal diet. Pettit *et al.* (2) showed that egg production was not affected when 6 per cent soybean oil meal was replaced by 6 per cent sunflower seed oil meal, or when 6 per cent soybean oil meal and 2.5 per cent meat meal were replaced by 9 per cent sunflower seed oil meal. All rations contained 5 per cent fish meal.

In a recent report from Ireland, Hale and Brown (1) compared laying diets in which fish meal or sunflower seed oil meal were the sole protein supplements. These investigators concluded from their studies that the quality of the protein in sunflower seed oil meal was satisfactory for egg production but that diets high in sunflower seed oil meal were relatively low in energy.

The experiments reported herein were conducted to gain further information on the value of sunflower meal as a major protein supplement in practical rations for hens confined in cages and floor pens. In these studies all mash diets were used, rather than the mash and grain diets employed in the works referred to above.

MATERIALS AND METHODS

A commercial source[4] of sunflower seed oil meal was used in this study. The meal was produced by the expeller process whereby it was cooked at 240° F. for approximately 30 minutes and finished in a conditioner at 260° F. for a further 3 minutes.

1. Contribution from Animal and Poultry Science Division, Experimental Farms Service, Ottawa, Ont.
2. *Present address:* Lederle Division, Cyanamid of Canada, Ltd., Montreal, Que.
3. Central Experimental Farm, Ottawa, Ont.
4. Co-op Vegetable Oils Ltd., Altona, Man.

TABLE 1.—COMPOSITION OF EXPERIMENTAL DIETS

	Experiment 1			Experiment 2		
	Ration No.			Ration No.		
	1	2	3	4	5	6
	lb.	lb.	lb.	lb.	lb.	lb.
Ground wheat	37.5	35.25	33.0	54.0	54.0	54.0
Ground oats	20.0	20.0	20.0	14.0	11.0	10.0
Ground barley	25.0	25.0	25.0	12.0	9.75	9.0
Meat meal (55%)	8.0	4.0	—	8.5	—	—
Soybean oil meal (44%)	—	—	—	—	11.5	—
Sunflower seed oil meal (41%)	—	4.75	9.5	—	—	13.0
Fish meal	2.5	2.5	2.5	2.0	2.0	2.0
Bone meal (steamed)	—	1.5	3.0	2.0	4.25	4.25
Common ingredients*	9.5	9.5	9.5	9.5	9.5	9.5
Calculated analysis						
Crude protein (%)	15.5	15.5	15.5	15.9	15.9	15.9
Calcium (%)	2.3	2.2	2.3	2.5	2.4	2.4
Total phosphorus (%)	0.8	0.8	0.8	1.0	1.0	1.0

**Experiment 1*—Dehydrated cereal grass, 2.5 lb.; ground limestone, 3.75 lb.; iodized salt, 0.5 lb.; feeding oil (2250A—300 D), 0.25 lb.; vitamin B_{12}, 300 mcg.; $MnSO_4$, 4 gm.; riboflavin, 110 mg.

Experiment 2—Whey powder, 2.0 lb.; dehydrated cereal grass, 2.25 lb.; ground limestone, 2.5 lb.; iodized salt, 0.5 lb.; feeding oil (2250A—300D), 0.25 lb.; vitamin B_{12}, 300 mcg.; $MnSO_4$, 4 gm.; riboflavin, 110 mg.

TABLE 2.—EFFECTS OF SUNFLOWER SEED OIL MEAL IN THE DIET ON THE PERFORMANCE OF BIRDS IN LAYING CAGES

Ration No.	1	2	3
Protein supplements			
Fish meal (%)	2.5	2.5	2.5
Meat meal (%)	8.0	4.0	—
Sunflower meal (%)	—	4.75	9.5
Birds housed (No.)	108	108	108
Eggs per bird*	175	178	181
Feed consumption			
Per 100 birds per day (lb.)	29	30	31
Per dozen eggs (lb.)	5.9	6.1	6.2
Mean body weight			
Initial (lb.)	6.5	6.6	6.6
Final (lb.)	7.2	7.3	7.3
Mortality (%)	8	15	10

*Corrected for mortality

Experiment No. 1

Three hundred and twenty-four Barred Plymouth Rock pullets, reared on range, were randomly assigned to individual laying cages at 200 days of age. An equal number of cages were randomly allotted to each of rations 1, 2 and 3 (Table 1). Ration 1 was a practical all-mash ration containing 8 per cent meat meal. Rations 2 and 3, also fed as all-mash rations, contained different levels of sunflower seed oil meal replacing meat meal and wheat in each case.

The birds were weighed individually on the first day on test and thereafter at intervals of 28 days. Mortality records were kept and data on individual feed consumption and egg production were obtained for a 301-day test period.

Experiment No. 2

Two hundred and forty Single Comb White Leghorn pullets, reared in confinement to 170 days of age, were randomly assigned to three pens in a nine-pen laying house. Similarly, 195 early-hatched and 195 late-hatched Barred Plymouth Rock pullets were each divided into three groups and each group was assigned to a laying pen. The ages of the early and late hatched Barred Rock pullets, on the date housed, were 200 and 130 days, respectively. Rations 4, 5 and 6 (Table 1) were assigned in such a manner that one pen of Leghorns, one pen of early-hatched Barred Rocks and one pen of late-hatched Barred Rocks received each ration. All rations, fed as mash, contained 2 per cent fish meal. The meat meal in ration 4 was replaced by soybean oil meal in ration 5, and by sunflower seed oil meal in ration 6.

The birds were weighed at the beginning of the test, and thereafter at 28-day intervals for a 280-day test period. Data on feed consumption and egg production for each pen were obtained on the basis of 28-day periods. Individual egg production records based on a 5-day trapping period per week were obtained and individual egg weights were recorded on a specified day each week.

RESULTS AND DISCUSSION

The results of Experiments 1 and 2 are summarized in Tables 2 and 3 respectively. In the first experiment, partial or complete substitution of sunflower seed oil meal for meat meal, in a ration containing 2.5 per cent fish meal, had no influence on egg production or body weight maintenance. There was a consistent trend towards increased feed consumption with higher levels of sunflower seed oil meal but these differences were non-significant when the data were analysed statistically.

In Experiment 2 the use of sunflower seed oil meal as a complete substitute for meat meal likewise had no effect on production or body weight maintenance. As expected, there were large differences in production between breeds and between ages of birds at housing. Although there was a significant difference between rations, the lower production of birds receiving the soybean oil meal ration was responsible for this difference.

TABLE 3.—THE EFFECTS OF SUBSTITUTING SOYBEAN OIL MEAL AND SUNFLOWER MEAL FOR MEAT MEAL ON THE LAYING HOUSE PERFORMANCE OF BIRDS CONFINED TO FLOOR PENS

Ration No.		4				5				6			
Protein supplements													
Fish meal	%	2.0				2.0				2.0			
Soybean oil meal	%					11.5							
Meat meal	%	8.5											
Sunflower meal	%									13.0			
		WL[1]	BR[2]	BR[3]	Av.	WL	BR	BR	Av.	WL	BR	BR	Av.
Birds housed	No.	80	65	65		80	65	65		80	65	65	
Eggs per bird*	No.	176	165	143	162	174	148	129	151	179	154	143	160
Feed consumption													
Per 100 birds/day	lb.	24.8	30.0	28.2	27.4	24.8	30.0	28.8	27.6	25.6	30.9	29.1	28.3
Per dozen eggs	lb.	4.7	6.1	6.6	5.6	4.8	6.8	7.6	6.1	4.8	6.7	6.9	5.9
Mean body weight													
Initial	lb.	4.1	6.0	4.6	4.8	4.0	6.2	4.6	4.8	4.0	6.1	4.6	4.8
Final	lb.	4.6	6.5	6.1	5.6	4.6	6.4	6.1	5.6	4.6	6.6	6.2	5.7
Mean egg weight	gm.	53.7	58.9	57.0	56.2	53.4	58.0	57.6	55.9	53.7	58.6	57.2	56.1
Mortality	%	12.5	12.3	9.2	11.4	8.7	7.7	7.7	8.1	1.2	7.7	13.8	7.1

1 White Leghorns
2 Early-hatched Barred Plymouth Rocks
3 Late-hatched Barred Plymouth Rocks
* Corrected for mortality

This may have been due to a methionine deficiency since the calculated methionine content of the soybean oil meal ration was below recommended requirements.

Feed consumption was highest on the ration containing sunflower seed oil meal, confirming the results of Experiment 1. Since low dietary energy is usually associated with high feed consumption, it appears that the sunflower seed oil meal diet was relatively low in energy.

Little difference existed in other data obtained. Egg weight, determined in Experiment 2, was approximately the same for all treatments. Differences in mortality could not be related to the ration being fed in either test.

Body weights, contrary to the results of Hale and Brown (1) were not adversely affected by the use of sunflower seed oil meal as a major protein source. Their high protein diets, however, contained approximately 17 per cent protein derived from mash and oats, which represents close to 20 per cent sunflower seed oil meal in the total diet. No more than 13 per cent sunflower seed oil meal was used in these tests. It is also possible that the sunflower seed oil meal used by Hale and Brown was lower in energy than that employed in these tests. This would be the case if the meal were prepared by the solvent extraction process, which removes more oil than the expeller process by which the meal in these tests was prepared.

The increased feed requirements on rations containing sunflower seed oil meal suggests that these diets were lower in energy than the meat meal diets. This might be expected as a result of the fact that sunflower meal is lower in protein and minerals than meat meal. Hence, greater amounts of low energy protein and mineral supplements must be incorporated in the ration at the expense of the higher energy grains.

In Experiment 2, feed consumption on the soybean oil meal diet was lower than on the sunflower meal ration. However, in this case, egg production was also lower which might account in part or in whole for the lower feed consumption. Therefore, one can make no inferences on the comparative energy levels of these two diets.

It is concluded from these experiments that sunflower seed oil meal is a very satisfactory protein supplement for laying rations, comparable to soybean oil meal for this purpose.

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TIMING THE TREATMENT OF CATTLE WITH TROLENE[1] FOR SYSTEMIC CONTROL OF THE CATTLE GRUBS *HYPODERMA LINEATUM* (DE VILL.) AND *H. BOVIS* (L.) IN ALBERTA AND BRITISH COLUMBIA[2]

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ABSTRACT

Experiments on timing the oral treatment of calves for cattle grub control with Trolene at 100 mg./kg. were carried out on ranches near Lethbridge, Alberta, and Kamloops, British Columbia. Groups of 30 and 25 calves, respectively, were treated in November, January, March, and April at Lethbridge and in December, January, February, and March at Kamloops.

Control of the pre-hypodermal grubs was equally effective on the first three treatment dates, varying from 94 to 98 per cent mortality. However, variations in the numbers of grubs precluded stating the mortality more precisely than within a range of 95 to 100 per cent at Lethbridge and 89 to 100 at Kamloops.

There was no significant difference in mortality between the two species of cattle grubs. However, the third hypodermal instar larvae of both species were less affected by the treatment ($P < .01$) than those of the preceding instars. Early autumn treatments are recommended to avoid the presence of third-instar larvae and to forestall early damage caused by the hypodermal grubs.

Slight symptoms of toxicity, in the form of lethargy and reduced food consumption at Kamloops and ataxia of the hindquarters at Lethbridge, were observed in the calves treated in December and January, respectively. The symptoms disappeared within 48 hours of treatment without the use of antidotes at either locality. The level of treatment used in this study was lower than that reported in the literature to produce first symptoms of toxicity.

INTRODUCTION

The promising results shown by a single, oral dose of Trolene in controlling first-instar cattle grubs migrating within the host (2, 6) required investigation under Canadian conditions. An experiment on the timing of such treatment at various dates in the cattle grub season at Lethbridge, Alberta, and Kamloops, British Columbia, was chosen for the following objectives: (a) to determine the best time for controlling cattle grubs at different stages of development; (b) to compare the mortalities of the three instars of the two species in the treated animals; and (c) to observe the effects of the treatment on cattle under various conditions of maintenance and weather throughout the grub season.

MATERIALS AND METHODS

Test Cattle and Sample Size

In Alberta, 150 Hereford and Hereford-cross calves, born between March 5 and June 1, were selected randomly from the 1956 calf crop of 210 on a ranch in the foothills west of Lethbridge. Throughout the warble

[1]O,O-dimethyl 0–2,4,5-trichlorophenyl phosphorothioate, obtained under the name "Dow ET-57" from Dow Chemical Co., Midland, Mich.

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fly season they ranged in an area adjacent to where mature grubs had dropped that spring. From the calf birth records and dates of fly activity it was known that all of the calves were exposed to attack from both species of warble fly. In British Columbia, 125 calves were selected randomly from the 1956 calf crop of 350 on a ranch east of Kamloops, after 50 late calves had been excluded. During the warble fly season the herd pastured in the semi-mountainous spring and summer range and were frequently up to 10 miles from grub-dropping locations. At the time of weaning the calves were assigned randomly to five experimental groups at both locations.

Previous knowledge of the wide standard deviations of the grub populations infesting calves determined the numbers of calves for each experimental group. From the formula $n_0 = \frac{t^2 s^2}{d^2}$ (1, p. 56), it was calculated that groups of fewer than 30 calves at Lethbridge and more than 30 at Kamloops were required as the probable adequate size at the level of 90 per cent probability with 25 per cent error. Groups of 30 calves were used at Lethbridge; however only 25 calves per group were used at Kamloops because of limited facilities.

Treatment of Cattle

At both locations the 5 groups of calves were treated in relation to the pertinent phases of development of the grub populations, as follows:—

Group 1 — untreated calves.

Group 2 — when grubs of *H. lineatum* were found lodged in the gullets of calves in the area—Lethbridge, November 7, 1956; Kamloops, December 3, 1956.

Group 3 — when grubs of *H. lineatum* had appeared in the backs of 50 per cent of the calves—Lethbridge, January 10, 1957; Kamloops*, January 7, 1957.

Group 4 — when the peak of *H. lineatum* and the beginning of *H. bovis* grub populations had appeared in the backs of the calves—Lethbridge, March 7, 1957; Kamloops, February 12, 1957.

Group 5 — when the peak of the *H. bovis* grub population had appeared in the backs of the calves—Lethbridge, April 18, 1957; Kamloops March 19, 1957.

Each calf was weighed on the day before treatment, after having been denied food and water overnight. In all cases the calves were treated at 100 mg. of Trolene per kg. of body weight (2, 7, 8). The treatments were based on the animal weight correct to the nearest 5 pounds and on the calculated weight of the chemical correct to the nearest 50 mg. Group 2 was treated by oral drench with a 25 per cent Trolene wettable powder and Groups 3, 4, and 5 with boluses containing 40 per cent Trolene.

Assessment of Control

At Lethbridge a cumulative grub count for each group was obtained weekly by charting the hypodermal grubs in their positions in the backs of the calves (4) up to the time of treatment. Beginning one week later

*This Kamloops group was treated before grubs appeared in the backs of the calves to accommodate the husbandry practices of the ranch.

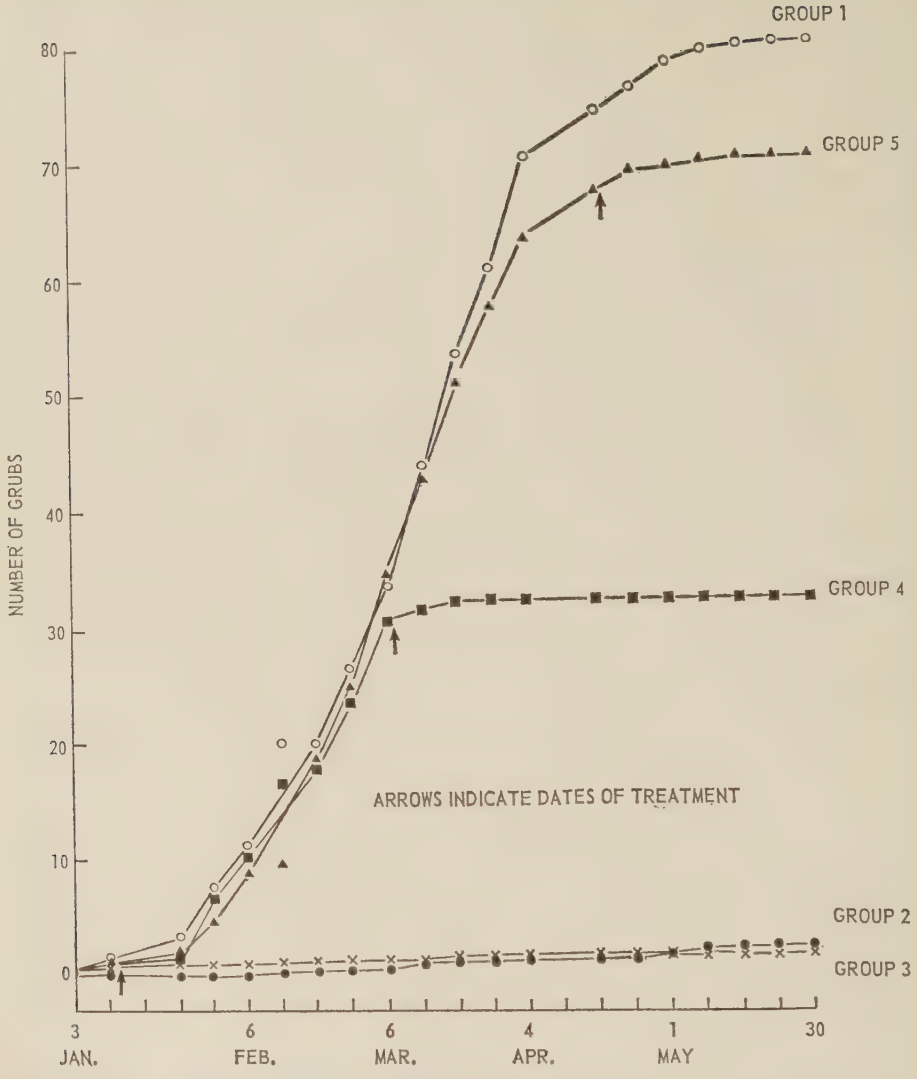

FIGURE 1. Mean cumulative number of grubs per calf collected weekly at Lethbridge, showing the effect of oral treatment with Trolene given on different dates to groups of 30 calves. Arrows indicate dates of treatment, except for Group 2, which was treated on November 7, 1956.

these and any new grubs to appear thereafter were squeezed out. At Kamloops a cumulative count of the grubs in the untreated Group 1 was obtained by weekly removal of grubs from the beginning of the season. For the treated groups, grubs were not assessed prior to treatment but were squeezed out beginning one week after the respective dates of treatment.

Mortality of the pre-hypodermal larvae was determined by the reduction in the number of grubs reaching the backs after treatment compared with the number collected in the untreated Group 1. To indicate the relative mortalities of the two species in the pre-hypodermal grub phase

TABLE I.—AVERAGE NUMBER[1] AND MORTALITY OF PRE-HYPODERMAL CATTLE GRUBS, *H. lineatum* AND *H. bovis*, AFTER TREATMENT WITH TROLENE AT 100 MG./KG. OF GROUPS OF 25 AND 30 CALVES AT KAMLOOPS, B. C., AND LETHBRIDGE, ALTA., RESPECTIVELY

		GROUP				
		1 (untreated)	2	3	4	5
A. No. grubs/calf in backs following treatment	K	—	0.9 ± 2.6	1.0 ± 2.1	1.0 ± 2.0	—[3]
	L	—	2.7 ± 3.5	1.2 ± 2.4 (3.7)[2]	1.4 ± 2.4	2.7 ± 2.6
B. No. grubs/calf in backs by end of season	K	30.2 ± 36.1	0.9 ± 2.6	1.0 ± 2.1	3.5 ± 6.4	—[3]
	L	80.0 ± 38.3	2.7 ± 3.5	2.2 ± 2.4 (5.9)[2]	32.5 ± 18.2	70.3 ± 23.4
C. No. grubs/calf in backs of untreated group following respective dates of treatment	K	—	30.2 ± 36.1	30.2 ± 36.1	18.0 ± 22.5	—[3]
	L	—	80.0 ± 38.3	78.2 ± 35.7	46.2 ± 28.6	5.6 ± 5.5
D. % mortality = $100\left(1-\frac{A}{C}\right)$	K	—	97	97	94	—[3]
	L	—	97	98 (95)[2]	97	53
E. Range of % mortality	K	—	93–100	94–100	89–100	—[3]
	L	—	95–98	97–100	95–99	28–77

K = Kamloops L = Lethbridge

[1]with S. D. (±)

[2]One animal in Group 3, suspected to have regurgitated its boluses, developed a total of 76 grubs. Numbers in parentheses include the grubs that developed in this animal. Others in the same group were observed to do so and were treated again.

[3]Observations were terminated too soon to permit gathering data.

the ratios of *H. lineatum.H. bovis* appearing in the backs after treatment were compared with those collected in the untreated group.

Mortality of the hypodermal grubs was calculated as the percentage of dead grubs over the total squeezed out. For comparison, natural mortality was determined at Lethbridge by weekly examination of a reference group of 30 animals from the same ranch, used in a different study, in which the grubs were allowed to develop to maturity. It was necessary to use this group because the schedule of squeezings in the designated untreated Group 1 interfered with the natural mortality, so that only 8 dead grubs were found among the 2,167 collected.

The data were analysed by analysis of variance and Student's "t" test.

RESULTS AND DISCUSSION

Grubs of *H. lineatum* appeared in the backs of the cattle in the period January 3—April 11 at Lethbridge and January 21—March 11 at Kamloops. Corresponding dates for *H. bovis* were January 23—May 30 at Lethbridge and February 5—April 1 at Kamloops, when the observations were discontinued. Hence, in Group 2 at Lethbridge and Groups 2 and 3 at Kamloops the treatments were directed against the full complement of both species in the pre-hypodermal stage; in Groups 3 and 4 at Lethbridge and Group 4 at Kamloops predominantly *H. bovis* were treated; in Group 5 at each locality only *H. bovis* larvae were treated.

In general, the average number of grubs at Lethbridge increased at the same rate in the five groups up to the time of treatment (Figure 1), suggesting that valid samples of the populations were being compared. An exception occurred on February 13 when, because of infectious keratitis in the herd, only 11, 8, and 12 calves were examined in Groups 1, 4, and 5, respectively. At Kamloops, where the variations in grub numbers were greater (Table 1, Group 1), the groups were not as comparable; e.g., averages of 2.5 and 12.4 grubs had appeared in the backs of Groups 4 and 1, respectively, prior to the time of treatment of the former group.

Mortality of Pre-hypodermal Grubs

Suppression of the grub population in each of the treated groups was immediate and obvious after treatment, except in Group 5 (Lethbridge) in which the number of grubs in the backs had begun to decline by the time of treatment (Figure 1). At both Lethbridge and Kamloops, some grubs survived in all of the treated groups (Table 1, line A) in contrast to the results of McGregor and Bushland (7). There was a highly significant difference in the average number of surviving grubs between the untreated and each of the treated groups ($P < .01$). Even Group 5 at Lethbridge was significantly different from Group 1 ($P < .02$). The average number of surviving grubs did not differ significantly among the treated groups (Table 1, line A), but the mortality in Group 5 was significantly lower ($P < .05$) than those in the first three groups (Table 1, line D). The available data were insufficient to determine whether there was indeed a decrease in effectiveness of the compound against the pre-hypodermal grubs in Group 5.

H. lineatum constituted 48 per cent of the grubs squeezed out of the cattle in Group 1, and 38 to 69 per cent of those surviving the treatments in Groups 2 to 5, inclusive. Since there was no significant difference between the treated and untreated groups, the treatment was equally effective against both species.

Statistical considerations are important in this type of experiment, the significance of which depends on comparing average numbers of grubs in relatively small groups of cattle. Variations in the numbers of grubs were minimized at each locality by choosing adequate samples of cattle from the same herd, which were subject to similar chances of infestation. The sample of 30 calves at Lethbridge was adequate at the level of 90 per cent probability and 15 per cent error. This is within the fiducial limits set beforehand. At Kamloops, 25 calves was an adequate sample at the level of 90 per cent probability and 40 per cent error. Even so, the scatter of grub counts in these cattle was considerable: the ranges of infestation in the untreated Group 1 at Lethbridge and Kamloops were about two and five times the means, respectively, and this was reflected in their standard deviations (Table 1, Group 1). Consequently it is unsafe to base conclusions on the simple ratio of treated: untreated grub populations without considering this ratio in relation to its standard error.

This was done by calculating a range of mortalities (Table 1) for each treatment, which gave a more realistic measure of cattle grub control by Trolene. The following calculations* were used:

$$S_p = \frac{1}{\overline{X}_u}\sqrt{\frac{S^2}{\overline{X}_t} + \frac{p^2S^2}{\overline{X}_u}}$$

where $\overline{X}_t$ and $\overline{X}_u$ are means of the treated and untreated grubs, respectively, $p = \overline{X}_t / \overline{X}_u$, and S_p, $S\,\overline{X}_t$ and $S\,\overline{X}_u$ are the respective standard errors of the ratio and of the corresponding means.

Since percentage survival $p = 100\,(1\text{-}p')$ (where p' is percentage mortality), the range of mortality is $p' \pm 2(100\,S_p)$ per cent. Thus, at Lethbridge the pre-hypodermal grub mortality of the first three treated groups is reasonably certain ($P < .05$) to lie between 95 and 100 per cent and at Kamloops between 89 and 100 per cent (Table 1).

Mortality of the Hypodermal Grubs (Lethbridge)

The timing schedule that was followed permitted comparison among different proportions of the three instars of the two species in Groups 3, 4, and 5 (Table 2). Because first-instar grubs did not occur in sufficient numbers to provide significant data as a separate category, they were combined with the second-instar in the calculations.

A highly significant difference ($P < .01$) was found between the mortalities of third-instar (average of 33 per cent) and earlier hypodermal larvae (average of 94 per cent). Otherwise the treatments were equally effective against the hypodermal larvae of both species in the three treated groups. Roth and Eddy (9) showed that the mortalities of third-instar

*Reimer, C., Statistical Laboratory, Science Service, Ottawa. *Private communication.*

TABLE 2.—AVERAGE NUMBER AND MORTALITY OF HYPODERMAL GRUBS SQUEEZED OUT ONE WEEK AFTER TREATMENT WITH TROLENE AT 100 MG./KG. AT LETHBRIDGE, ALTA.

	GROUP					
	3		4		5	
	INSTAR					
	I & II	III	I & II	III	I & II	III
No. grubs/calf						
H. lineatum	1.2	0	8.9	16.8	0	0
H. bovis	0	0	1.8	0.8	0	32.0
Total	1.2		28.3		32.0	
%Mortality						
H. lineatum	89	–	98	35	–	
H. bovis	–	–	96	32	–	31
Total	89		58		31	
% Mortality in untreated reference group	0		8		10	
Corrected[1]% mortality	89		54		23	

[1]By Abbott's formula (3, p. 88)

larvae increased when a longer time was allowed between treatment and sampling. However, they also concluded that the third-instar larvae were more resistant than the first- and second-. By examining hides in slaughterhouses we have seen that the distinct cyst wall is usually found around the third-instar larvae; this possibly presents a barrier to the penetration of the systemic insecticide into the warble. Our apparent decrease in total mortality as the season progressed (more apparent when corrected for natural mortality by Abbott's formula (3, p. 88)) was attributed to the increase in proportions of third-instar larvae present on the different dates of treatment (Table 2). A highly significant difference was found between the mortality in each treatment group and the natural mortality for the corresponding week.

Considering the results in the preceding sections, it was concluded that all but the third-instar larvae of both species were susceptible to the treatment with Trolene. It is suggested that cattle be treated before the hypodermal phase of the grubs in order to avoid the presence of the third-instar larvae and to prevent early hide and meat damage. In both Alberta and British Columbia this would be from September until mid-December.

Other Considerations of Treatment

The effective dates of treatment usually coincide with the autumn round-up and other preparations for wintering.

Both the bolus and oral drench were awkward to administer; the bolus method was preferable in colder weather but regurgitation of boluses (Table 1, footnote) is a drawback.

At Kamloops minor toxic symptoms appeared in Group 2, treated with the oral drench shortly after weaning and vaccination of heifers for brucellosis. Three steers and two heifers showed general loss of vigour within 24 hours of treatment. The affected animals were not observed to feed until they recovered. All recovered without the use of an antidote within 48 hours of treatment.

At Lethbridge ataxia of the hindquarters appeared in 10 calves within 24 hours of treating Group 3 with boluses. The calves had been weaned about two months previously. Among the circumstances attending this treatment were sub-zero temperatures, pasteurellosis and infectious keratitis in the herd, and limited access to drinking water. When the affected animals were forced to exercise for a short time, the symptoms disappeared within 48 hours without the use of an antidote.

Occurrence of the dissimilar symptoms in the two localities did not seem to be correlated with weather, disease, and time after weaning.

In Texas, Radeleff and Woodard (8) did not find symptoms of toxicity in cattle treated with Trolene below the level of 125 mg./kg. Jones *et al.* (5) experienced no difficulties when cattle in Nebraska were treated at 110 mg./kg. on the basis of guessed weights of the cattle. However, the characteristic narrow margin between effective and mildly toxic doses (2, 7, 8) seems to necessitate accurate cattle weights and care in measuring the dosage.

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LOW-LEVEL FEEDING OF TROLENE[1] FOR CONTROL OF THE CATTLE GRUBS *HYPODERMA LINEATUM* (DE VILL.) AND *H. BOVIS* (L.)[2]

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ABSTRACT

Calves were fed individually for 18 days on a ration of crushed oats treated with Trolene to give a daily dosage of 10 mg./kg. This treatment produced 94 per cent mortality of pre-hypodermal cattle grubs. This was not significantly different from 97 per cent mortality obtained with a single treatment by boluses at 100 mg./kg. The low-level treatment had no effect on the mortality of the pre-hypodermal grubs during the first week of treatment but reached its full effect before the beginning of the third week. Of the hypodermal grubs present at the time of treatment, 94 per cent died and the remainder pupated. The only symptom of toxicity observed was mild diarrhoea in the low-level-treated calves.

In a field experiment, two groups of calves that had consumed treated range blocks daily at averages of 7.7 and 4.2 mg. Trolene/kg. for 93 and 64 days showed 95 and 88 per cent mortality, respectively, of the pre-hypodermal grubs. By comparison, another group of calves, treated with boluses at 110 mg. Trolene/kg., showed 80 per cent mortality. The average number of grubs surviving the three treatments were significantly different from each other and from the untreated controls ($P < .01$). All treatments were begun before hypodermal grubs had appeared. No symptoms of toxicity were seen in the calves of the two low-level-treated groups; ataxia of the hindquarters was observed in the bolus-treated calves on the day following treatment, but these symptoms disappeared on the same day without the use of an antidote.

INTRODUCTION

Previous information has shown that feeding Trolene to cattle at 5, 10, and 20 mg. kg. daily for 7 months produced complete control of cattle grubs without producing toxic symptoms[6] in the cattle. This method of treatment required further investigation as a form more acceptable than the cumbersome bolus or oral drench, both of which produced toxic symptoms in cattle at a single dose of 100 mg./kg. (4). The objectives of a laboratory experiment were to delimit the number of days of low-level treatment required to produce control of grubs comparable to that produced by a single dose at 100 mg. kg. and to determine the percentage of grubs that survive such treatment and pupate. The objective of a field experiment was to assess the effectiveness of the low-level treatment method under free choice conditions of feeding on a ranch.

MATERIALS AND METHODS

Individual Feeding Laboratory Equipment

In November 1956, 60 weaner calves were selected randomly from the herd that was used in Alberta in a concurrent study (4). They were brought to the laboratory and distributed randomly into low-level-treated and

[1]O, O-dimethyl O-2,4,5-trichlorophenyl phosphorothioate, obtained under the name Dow ET-57 from Dow Chemical Company, Midland, Mich.

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[3,4,5]Associate Entomologist, Assistant Entomologist, and Technician, respectively, Livestock Insect Section.

[6]Sturdy, R. A., Moorman Mfg. Co., Quincy, Ill. *Personal communication.*

untreated groups of 30 calves each. This sample was calculated to be adequate at the level of 95 per cent probability and 15 per cent error.

Low-level treatment began on March 5, 1957, after a number of grubs had already appeared in the backs of the cattle, and was continued until the infestation was observed to be under control. Crushed oats in a commercial feed mixer were sprayed with an emulsion at the rate of 79 grams of Trolene (i.e. 158 ml. concentrate × 500 mg. ml.) per 100 pounds of oats. Once daily the cattle of each group were stanchioned and individually fed about 2 pounds of oats, adjusted to the cattle weights (average 358 lb. or 163 kg.) so that the treated animals received an average dose of Trolene of 10 ± 1 mg./kg. To compare this treatment with a single bolus treatment at 100 mg./kg., the data were used from another group of the same herd, treated on March 7 in the concurrent experiment (4).

The grubs were counted weekly by charting their positions in the backs of the cattle (2) from the beginning to the end of the hypodermal grub season. Mortality of the pre-hypodermal grubs was calculated as previously described (4). Canvas girdles, modified from those of Gregson and Holland (2), were used to collect grubs from both the treated and untreated cattle from March 6 to the end of the season. Any grubs that dropped into the girdles were allowed to pupate. The hypodermal grub mortality was expressed as the percentage of hypodermal grubs that failed to pupate.

Group Feeding Field Experiment

In November 1957, four groups of weaner calves were selected for a test of free choice ingestion of feed treated with Trolene. All ranged in the same area and were equally exposed to attack from both species of the warble fly. The experimental groups, which were maintained separately during the period of low-level treatment, were:—

Group 1 — 20 calves untreated.
Group 2 — 20 calves, treated with Trolene boluses at 110 mg./kg. on December 3.
Group 3 — 40 calves, supplied at all times with 3 Mintrate* Range Blocks (Red), containing 0.4 per cent Trolene, which they consumed at a rate to give a daily Trolene dose of about 10 mg./kg. from November 28 until the blocks were eaten.
Group 4 — 36 calves, similarly supplied with blocks* containing 0.2% Trolene to give a daily Trolene dose of about 5 mg./kg.

All grubs in Groups 1 and 2 were squeezed out weekly from the beginning of January, when the first grubs appeared in the backs. The grubs in Groups 3 and 4 were counted by charting (2) at monthly intervals until the end of February and were squeezed out weekly thereafter.

The data from both experiments were analysed by analysis of variance and Student's "t" test.

RESULTS AND DISCUSSION

Individual Feeding Laboratory Experiment

After 18 days the daily, low-level treatment with Trolene at 10 mg./kg. was discontinued. The average increase in cattle weight was 1 pound

*Obtained from Moorman Mfg. Co., Quincy, Ill.

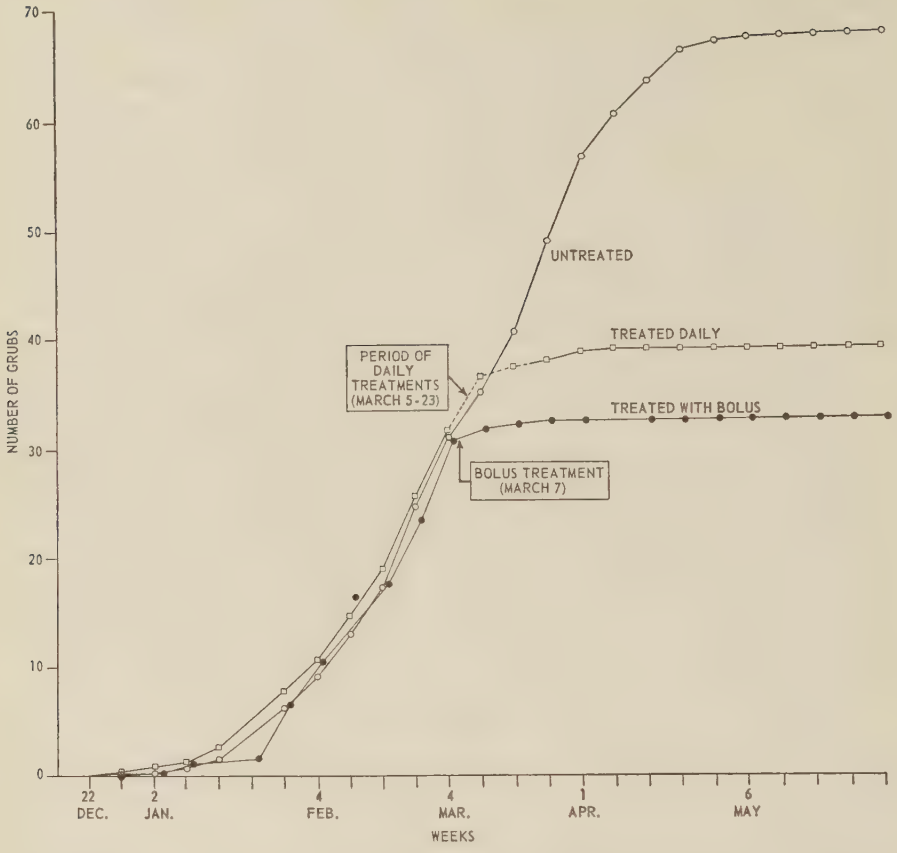

FIGURE 1. Cumulative average numbers of grubs per calf appearing in the backs of three groups of 30 calves: untreated; treated daily March 5-23, 1957, with Trolene in the feed at 10 mg./kg.; treated once March 7, 1957, with Trolene boluses at 100 mg./kg. [Redrawn from (4)]. Lethbridge, Alberta.

per day, and therefore the dosage diminished proportionately to 9.6 mg./kg. on the last day of treatment. At the beginning, two of the calves did not readily accept the treated oats but were kept stanchioned until they had eaten most of their rations. However, this reluctance to feed was not seen after the first 3 days.

Until the time of treatment, the average number of grubs in the untreated and low-level groups was increasing at the same rate (Figure 1). This was comparable to that for the single bolus-treated group at 100 mg./kg. in the concurrent experiment (4). During the first week of low-level treatment there was no discernible mortality of pre-hypodermal grubs whereas an immediate mortality occurred after the bolus treatment. A controlling effect equal to that of the bolus treatment became evident in the second week of low-level feeding.

Although the average mortality of the pre-hypodermal grubs in the low-level group was only 80 per cent calculated from the beginning of treatment, it was 94 per cent calculated from the end of treatment (Table 1).

TABLE 1.—EFFECT ON THE CATTLE GRUBS *H. lineatum* AND *H. bovis* OF TREATING CALVES WITH TROLENE AT 10 MG./KG. FOR 18 DAYS. LABORATORY TEST, LETHBRIDGE, ALTA., 1956-57

Position of grubs in host	Average[1] number and mortality of cattle grubs	
	Treated (30 calves)	Untreated (30 calves)
A. In back prior to treatment[2] period	31.7 ± 25.7	30.9 ± 17.6
B. Entering back during treatment period	6.1 ± 8.5	17.8 ± 6.8
C. Entering back following treatment period	1.0 ± 2.4	18.7 ± 9.3
D. Total entering back (B+C)	7.1 ± 9.0	36.5 ± 17.0
E. Final average number of grubs (A+B+C)	38.8 ± 15.2	67.4 ± 20.9
Per cent mortality of pre-hypodermal grubs		
a[3] calculated from beginning of treatment	80	—
b[4] calculated from end of treatment	94	—

[1]With S. D. (±).
[2]Treatment period March 5–23 inclusive.
[3,4] $= 100\left(1 - \frac{\text{no. grubs in treated group}}{\text{no. grubs in untreated group}}\right)$ in lines C and D, respectively.

The latter mortality was not significantly different from the 97 per cent obtained with the single bolus treatment (4). Therefore, the chief difference in mortality of grubs between the low-level and the bolus treatments was in the number of pre-hypodermal grubs that survived in the former during the period of treatment. Since bolus treatment was equally effective whenever given during the grub season (4), it seems probable that this difference would be eliminated by starting the low-level treatments before the grubs appear in the backs.

Since 2.4 of the 38.8 grubs (Table 1) in the backs of the low-level-treated cattle pupated, the mortality of the hypodermal grubs was 94 per cent [i.e., $100\left(1-\frac{2.4}{38.8}\right)$ per cent]. All but one of these grubs had appeared in the backs before the end of treatment. This single grub was *H. bovis*, the only one of that species to survive in the entire group. In the untreated group 6.9 and 16.0 grubs of *H. lineatum* and *H. bovis*, respectively, of the 67.4 grubs in the backs pupated. Therefore the mortality was 66 per cent. Application of Abbott's formula (1, p. 88) to these data gave a relative hypodermal grub mortality of 82 per cent resulting from the low-level treatment.

Group Feeding Field Experiment

The calves in Groups 3 and 4 consumed the Trolene at average daily rates of 7.7 and 4.2 mg./kg. (Table 2), calculated on the basis of average calf weights of 300 and 380 pounds (or 136 and 173 kg.), respectively, at the beginning of treatment. The intended dosage levels of 10 and 5 mg./kg., respectively, were not reached because of mitigating external factors. For example, the presence of salt from other sources reduced the rate of consumption of the Mintrate blocks, which in themselves contain 14 per

TABLE 2.—EFFECTS ON PRE-HYPODERMAL CATTLE GRUBS (*H. lineatum* AND *H. bovis*) OF SINGLE BOLUS AND DAILY LOW-LEVEL TREATMENTS OF CALVES WITH TROLENE. FIELD TEST, LETHBRIDGE, ALTA., 1957-58

Treatment groups	No. calves	No. days treated	Consumption of Trolene (mg./kg.)		Average[1] no. grubs per calf to survive	Per cent[2] mortality	Range of per cent mortality
			Daily	Total			
Group 1	20	—	0	0	59.6 ± 35.8	—	—
Group 2	20	Single bolus treatment	–	110	11.9 ± 9.0	80	71–89
Group 3	40	93	7.7	716	2.8 ± 5.0	95	92–98
Group 4	36	64	4.2	269	7.0 ± 8.2	88	83–93

[1]With S.D. (±)

[2]$=100\ (1-\frac{\text{no. grubs in treated group}}{\text{no. grubs in untreated group}})$

cent salt. In this experiment the calves of Group 3 consumed a daily average Trolene dose of 6.6 mg./kg. for the first 22 days, when they had access to other salt, and an average of 8.0 mg./kg. for the rest of the period, after the salt had been removed. On the other hand, the calves of Group 4 consumed a daily Trolene dose of 5.3 mg./kg. for the first 34 days in the absence of other salt and 3.2 mg./kg. for the remaining 30 days, after salt was made available.

The sample of 20 calves in the untreated Group 1 produced an average of 59.6 ± 35.8 grubs per calf (Table 2), indicating adequacy at 90 per cent probability and 23 per cent error. This was not as satisfactory as in the laboratory experiment, where 30 calves constituted the sample group, but it was within the fiducial limits selected beforehand. Analysis showed that the mortality of 95 per cent (Table 2) produced by daily consumption of Trolene at 7.7 mg./kg. for 93 days (Group 3) was significantly higher ($P < .01$) than the 88 per cent produced by 4.2 mg./kg. daily for 64 days (Group 4). These were significantly higher ($P < .01$) than the 80 per cent mortality from the bolus treatment at 110 mg./kg. (Group 2). Thus the mortalities varied proportionately with the total dose of Trolene (Table 2). This experiment indicated that the low-level feeding method is practicable in the field. However, in this experiment the total consumption of Trolene by this method was considerably higher than that given in a single dose.

No symptoms of toxicity as described by Radeleff and Woodard (3) were observed in the cattle given low-level treatments. However, mild diarrhoea was noticeable in the group treated at the laboratory at 10 mg./kg. for 18 days. Sturdy* found that only occasional diarrhoea appeared in a group of 5 cattle with Trolene at 20 mg./kg. for 213 days, and none in similar groups at 5 and 10 mg./kg.

In the field experiment of 1958, ataxia of the hindquarters was observed in 15 of the 20 calves treated by bolus (Group 2). The nature and duration of these symptoms were the same as those described previously (4).

*Sturdy, R. A., Moorman Mfg., Co., Quincy, Ill. *Personal communication.*

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THE INFLUENCE OF THE AMOUNT OF PROTEIN AND ENERGY IN THE RATION OF REPLACEMENT EWE LAMBS ON BODY WEIGHT GAINS AND WOOL PRODUCTION[1]

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ABSTRACT

Three experiments were carried out with replacement ewe lambs to determine the influence of feeding rations containing three levels of protein, each at two levels of digestible energy. The three levels of protein were approximately 8, 9.5, and 11 per cent in the first two experiments, and 6, 9, and 12 per cent in the third experiment.

Increasing the amount of protein in the ration resulted in an increase ($p < .05$) in the apparent digestibility of the protein, but no change in the percentage of protein retained or in the digestibility of the dry matter and gross energy. Increasing the digestible energy content of the ration by substituting corn starch for wheat straw or oat hulls reduced ($p < .05$) the digestibility and retention of protein in Experiments 2 and 3, but had no effect in Experiment 1.

Body weight gains and wool growth of lambs fed rations containing wheat straw or oat hulls did not increase to so great an extent as those fed corn starch. This would indicate that energy was a limiting factor for maximum production in the lower digestible energy rations. In general, weight gains and wool production increased ($p < .05$) when the daily intake of D.C.P. was increased from approximately 0.10 to 0.13 pounds. Increasing the D.C.P. from 0.13 to 0.16 pounds (0.19 in Experiment 3) caused no further increase in body gains but increased ($p < .05$) wool production.

On the basis of these results, the average D.C.P. requirements of a ewe lamb weighing 85 pounds and consuming 1.3 pounds T.D.N. was 0.13 pounds (0.16 pounds when wool production was considered).

INTRODUCTION

Many experiments have been conducted to determine the influence of the amount of protein in the ration of mature ewes on lamb and wool production (5, 6, 12, 13, 14, 17). Few experiments have been reported on the influence of the level of protein in the ration of ewe lambs after weaning on body weight gains and wool production. Such information is needed if rations are to be formulated that will result in replacement ewe lambs making satisfactory but economical growth.

Keith *et al.* (7) compared rations containing 7.1, 8.9, 10.8, and 12.7 per cent protein for ewe lambs weighing between 75 and 100 pounds and, on the basis of gains and feed efficiency, concluded that ewe lambs require a ration containing approximately 13 per cent protein (0.23 pounds D.C.P. daily).

Bush *et al.* (4) at Cornell University found that fattening lambs fed on rations containing 11.8 per cent protein made greater daily gains than those fed rations containing 10.0 or 11.0 per cent. However, there was no difference in feed efficiency between the three groups. These results were in general agreement with previous results from that institution.

[1] Contribution from the Division of Animal and Poultry Science, Experimental Farms Service.

TABLE 1.—THE DAILY D.C.P. AND T.D.N. REQUIREMENTS FOR GROWING EWE LAMBS AS TAKEN FROM PUBLISHED LITERATURE

Weight of lamb	Morrison[1]		N.R.C.[2]		Blaxter & Mitchell[3]	
	T.D.N.	D.C.P.	T.D.N.	D.C.P.	T.D.N.	D.C.P.
lb.						
60	1.4	0.16	1.6	0.16	1.6	0.17
70	1.6	0.19	1.7	0.15	1.7	0.17
100	1.8	0.21	1.7	0.14	1.7	0.16
120	2.0	0.23	1.7	0.14	1.7	0.14

[1]Morrison (10). Average of minimum and liberal recommendations.
[2]Pope *et al.* (11)
[3]Blaxter and Mitchell (1). Average of requirement when on a good and on a poor feed supply.

Mitchell *et al.* (9), on the basis of carcass analyses and the digestibility and biological values of the protein of feeds, calculated that the daily D.C.P. requirement of ewe lambs weighing 50, 70, 90, and 110 pounds was 0.127, 0.115, 0.104, and 0.09 pounds, respectively.

Morrison (10) and Pope *et al.* (11) have reviewed the literature on the protein requirements of lambs and have proposed standards for lambs of various weights. These standards for D.C.P. and total digestible nutrients (T.D.N.) are tabulated in Table 1.

Blaxter and Mitchell (1) also have calculated the protein requirements in terms of D.C.P. for cattle and sheep when fed good and poor feeds. Their requirements for Shropshire ewe lambs are tabulated in Table 1. Lofgreen *et al.* (8) have criticized the method of Blaxter and Mitchell in calculating the protein requirements of growing ruminant animals and have shown that their values for heifers were too high at body weights below 500 pounds and too low at weights above 500 pounds. The lack of agreement between various standards that have been proposed further emphasizes the need for studies on the protein requirements of ewe lambs.

It is known also that with certain species of animals the energy content of a ration can influence the utilization of protein and hence the amount of protein that needs to be supplied to the animal. In a previous paper (17) the published information on this subject as it applies to ruminant nutrition was reviewed.

Three experiments were carried out at the Regional Research Station, Lethbridge, Alberta, with ewe lambs after weaning, to determine the influence of feeding rations containing three levels of protein, each at two levels of digestible energy, on body weight gains and wool production. The results of these experiments are reported in this paper.

TABLE 2.—THE PERCENTAGE COMPOSITION AND CHEMICAL ANALYSIS OF THE RATIONS USED IN EXPERIMENTS 1, 2, AND 3. (90% DRY MATTER)

	Rations					
	A	B	C	D	E	F
	Percentage Composition—Experiment 1 [1,2]					
Grass hay	60	60	60	60	60	60
Wheat straw	10	10	10	—	—	—
Corn starch	—	—	—	10	10	10
Linseed oilmeal	—	9	18	—	9	18
Wheat and barley	18	9	—	18	9	—
Dried molasses beet pulp	8	8	8	8	8	8
Beet molasses	3	3	3	3	3	3
Bonemeal and salt (1:1)	1	1	1	1	1	1
	Percentage Composition—Experiment 3					
Grass hay	50	50	50	50	50	50
Oat hulls	30	30	30	—	—	—
Corn starch	—	—	—	28	28	28
Soybean meal	—	7.5	15	2	9.5	17
Urea	—	0.5	1	—	0.5	1
Wheat	16	8	—	16	8	—
Beet molasses	3	3	3	3	3	3
Bonemeal and salt (1:1)	1	1	1	1	1	1
	Chemical Analysis—Experiment 1					
Protein (N x 6.25)	7.9	9.5	10.7	8.4	9.4	11.0
Crude fibre	27.9	28.4	28.1	25.0	24.6	24.2
Ether extract	1.6	1.8	2.1	1.7	1.9	2.0
Ash	6.1	6.4	6.5	5.8	6.1	6.3
Gross energy (Cal./gm.)	3.9	4.0	4.0	4.0	4.0	4.0
	Chemical Analysis—Experiment 2					
Protein (N x 6.25)	8.1	9.4	11.2	7.9	9.2	11.1
Crude fibre	24.0	25.0	25.9	17.8	17.9	18.3
Ether extract	2.3	2.5	2.6	2.2	2.4	2.7
Ash	7.7	7.8	8.3	7.0	7.1	7.5
Gross energy (Cal./gm.)	3.9	4.0	4.0	3.9	4.0	4.0
	Chemical Analysis—Experiment 3					
Protein (N x 6.25)	6.2	8.8	11.6	6.1	9.2	12.2
Crude fibre	27.2	27.8	28.6	18.2	18.4	18.6
Ether extract	1.6	1.8	2.0	1.4	1.5	1.5
Ash	6.3	6.5	6.8	4.6	5.0	5.2
Gross energy (Cal./gm.)	3.8	3.9	3.8	3.8	3.8	3.8

[1]The composition of the rations in Experiment 2 differed from those in Experiment 1, in that rations A, B, and C contained 14 per cent straw and 4 per cent dried molasses beet pulp (D.M.B.P.), and rations D, E, and F contained 14 per cent starch and 4 per cent D.M.B.P.

[2]Sufficient dry stabilized vitamin A concentrate was added to each ration to provide approximately 1,000 i. u. per lamb daily.

PROCEDURE

Experiment 1

Forty-eight ewe lambs (mainly of Rambouillet and Corriedale breeding) approximately 6 months old, were divided into six lots of 8 lambs each on the basis of body weight. Rations containing three levels of protein (approximately 8, 9.5, and 11 per cent) each at two levels of digestible energy were

TABLE 3.—THE AVERAGE APPARENT DIGESTIBILITY COEFFICIENTS FOR DRY MATTER, PROTEIN, CRUDE FIBRE, AND GROSS ENERGY, AND THE PERCENTAGE PROTEIN RETAINED OF THE RATIONS FED DURING EXPERIMENTS 1, 2, AND 3

	Experiment	Rations					
		A	B	C	D	E	F
Dry matter	1	62	61	62	64	64	64
	2	62	58	57	64	67	64
	3	53	56	53	65	64	68
Protein (N x 6.25)	1	57	60	63	59	60	62
	2	52	59	66	47	57	60
	3	67	70	73	47	54	70
Crude fibre	1	62	61	63	64	61	62
	2	65	60	60	61	67	67
	3	45	50	49	32	38	47
Gross energy	1	60	60	61	62	63	62
	2	64	59	60	65	68	64
	3	53	56	52	62	63	67
% Protein retained of that fed	1	22	16	15	19	23	17
	2	12	19	13	6	20	12
	3	23	28	26	10	16	18

fed. The higher levels of protein were obtained by substituting linseed oilmeal for an equal weight of a mixture of barley and wheat, and the higher level of digestible energy was obtained by substituting corn starch for an equal weight of wheat straw. The composition and chemical analyses of the rations used in Experiments 1, 2, and 3 are shown in Table 2.

The grass hay was fed in the chopped form, and the other ingredients were mixed and pelleted and fed in that form.

The lambs were fed twice daily in individual pens. At the beginning of the experiment an attempt was made to feed all lambs about the same daily amount of feed. However, this proved to be difficult as certain lambs temporarily went off feed. Thereafter, the lambs were fed *ad libitum*. They were weighed at 2-week intervals. The number of days on feed in each experiment is shown in Table 4.

A 2 x 2 cm. area was tattooed on the right shoulder of each lamb at the beginning of the experiment. The wool on these areas was removed at 60-day intervals. Weights of clean wool, fibre lengths, and fibre thicknesses were determined on these samples.

Digestibility coefficients of the proximate principles and nitrogen balances for each ration were determined at the end of the feeding experiment using two lambs from each lot. The collection period was of 10 days' duration preceded by a 10-day preliminary period.

In Experiments 2 and 3 the lambs were handled and fed as described above and similar data were collected.

Experiment 2

Forty-eight ewe lambs of mixed breeding, approximately 7 months old, were divided into six lots of 8 lambs each. The percentage composition of the rations fed in this experiment were essentially the same as those fed in Experiment 1, with the exception that wheat straw made up 14 per cent of rations A, B, and C, and corn starch made up 14 per cent of rations D, E, and F, instead of 10 per cent as in Experiment 1. The amount of dried molasses beet pulp was reduced accordingly.

Experiment 3

Forty-eight ewe lambs (Romnelet and Corriedale breeding), approximately 6 months old, were divided into six lots of 8 lambs each on the basis of body weight. The percentage composition of the rations fed was changed somewhat from those fed in Experiments 1 and 2 in order to obtain greater differences in digestible energy and protein contents between the rations (see Table 2).

TABLE 4.—THE AVERAGE DAILY TOTAL FEED, (D.C.P., T.D.N.) DIGESTIBLE ENERGY (THERMS) INTAKE, BODY WEIGHT GAINS, AND WOOL PRODUCTION OF EWE LAMBS AS INFLUENCED BY THE LEVEL OF PROTEIN AND ENERGY IN THE RATION

Lot No.	A	B	C	D	E	F
			Experiment 1			
Av. initial weight of lambs.....(lb.)	61	61	60	60	61	60
Av. daily feed intake.....(lb.)	1.9	2.0	2.0	1.9	1.9	2.0
Av. daily D.C.P. intake[1].....(lb.)	0.10	0.13	0.15	0.10	0.13	0.15
Av. daily dig. energy intake[1].....(therms)	2.2	2.2	2.2	2.3	2.3	2.3
Av. daily T.D.N. intake[1].....(lb.)	1.0	1.1	1.1	1.1	1.2	1.2
Av. D.C.P./lb. T.D.N.....(lb.)	0.10	0.12	0.14	0.09	0.11	0.13
Av. total body gains [1,2] (189 days).....(lb.)	21	24	25	24	26	28
Av. weight wool[1,2,3].....(gm.)	0.41	0.46	0.46	0.42	0.45	0.53
			Experiment 2			
Av. initial weight of lambs.....(lb.)	74	75	72	71	72	72
Av. daily feed intake.....(lb.)	2.2	2.3	2.4	2.1	2.2	2.3
Av. daily D.C.P. intake[1].....(lb.)	0.11	0.14	0.18	0.10	0.13	0.16
Av. daily dig. energy intake[1].....(therms)	2.5	2.5	2.5	2.7	2.7	2.7
Av. daily T.D.N. intake[1].....(lb.)	1.2	1.2	1.2	1.3	1.3	1.3
Av. D.C.P./lb. T.D.N.....(lb.)	0.09	0.12	0.15	0.08	0.10	0.12
Av. total body gains[1,2] (189 days).....(lb.)	22	25	28	26	32	35
Av. weight clean wool[1,2,3].....(gm.)	0.37	0.45	0.49	0.40	0.49	0.51
			Experiment 3			
Av. initial weight of lambs.....(lb.)	83	82	81	82	82	84
Av. daily feed intake.....(lb.)	2.6	2.7	2.6	1.7	2.2	2.0
Av. daily D.C.P. intake[1].....(lb.)	0.08	0.14	0.19	0.07	0.12	0.19
Av. daily dig. energy intake[1].....(therms)	2.2	2.2	2.2	2.5	2.6	2.6
Av. daily T.D.N. intake[1].....(lb.)	1.1	1.1	1.1	1.3	1.3	1.3
Av. D.C.P./lb. T.D.N.....(lb.)	0.07	0.13	0.17	0.05	0.09	0.15
Av. total body gain[1,2] (112 days).....(lb.)	10	11	14	13	21	22
Av. weight clean wool[1,2,3].....(gm.)	0.31	0.37	0.43	0.32	0.46	0.58

[1]Adjusted by analysis of covariance to the average feed intake
[2]Significant difference (P = 0.05) between lots

	Total Gains	*Weight Wool*
Experiment 1	3 lb.	0.06 gm.
Experiment 2	3 lb.	0.08 gm.
Experiment 3	4 lb.	0.05 gm.

[3]Weight of wool from a 2 x 2 cm. area

RESULTS AND DISCUSSION

Lambs fed rations containing corn starch consumed less feed than lambs fed rations containing wheat straw or oat hulls. In order to compare rations, the average D.C.P. and digestible energy intakes, body gains, and wool production were adjusted for each lot by the analysis of covariance (15) to an average feed consumption within each experiment. Only the adjusted values will be discussed in this paper.

Level of Protein

When the protein content of the rations was increased there was an increase ($p < .05$) in the apparent digestibility of the protein but no increase in the percentage of the protein retained or in the digestibility of dry matter, gross energy, or crude fibre, with the exception that in Experiment 3 increasing the protein content of the starch-containing rations did increase the digestibility of the crude fibre (see Table 3).

The body weights and wool production of lambs fed rations containing wheat straw or oat hulls (Rations A, B, and C) did not respond to increased intakes of D.C.P. to so great an extent as those from lambs fed corn starch. This indicates that energy was the limiting factor for maximum gains and wool production in the straw- and hull-containing rations. However, on the basis of digestible energy, the difference between the straw- or hull-containing rations and the starch-containing rations was not sufficient to account for the difference in gains of the lambs (see Table 4). Blaxter and Graham (2) have shown that the digestible and metabolizable energy content of certain rations were not good indices of the energy retention (net energy) by the animal.

When the three experiments were considered together, body weight gains and wool production generally were increased ($p < .05$) when the D.C.P. intake was increased from approximately 0.10 to 0.13 pounds. Increasing the D. C.P. intake to 0.16 pounds (0.19 pounds in Experiment 3), caused no further increase in body gains but increased ($p < .05$) wool production. On the basis of these results, the daily D.C.P. requirements of ewe lambs weighing an average of 85 pounds and consuming approximately 1.3 pounds T.D.N. is 0.13 (0.16 pounds if increased wool production is considered to be important). Pope *et al.* (11) recommended a D.C.P. intake of 0.15 pounds for ewe lambs weighing 80 pounds and receiving 1.7 pounds T.D.N. daily. The amounts suggested by Morrison (10), Blaxter and Mitchell (1), and Keith *et al.* (7) were higher than those recommended by Pope *et al.* In previous experiments (17) it was found that the clean wool production from mature ewes on a low protein-high energy ration was depressed ($p < .05$). However, this phenomenon was not observed with ewe lambs.

Level of Energy

When corn starch was added to the ration in the place of wheat straw or oat hulls, there was an increase ($p < .05$) in the digestibility of the dry matter and gross energy. The addition of corn starch reduced the apparent digestibility and retention of protein in Experiments 2 and 3 but not in Experiment 1 (see Table 3).

When the digestible energy content of the rations was increased by substituting corn starch for wheat straw or oat hulls, body weight gains were increased significantly ($p<.05$) at the different levels of D.C.P. intake in seven cases out of nine. However, wool production was increased significantly ($p<.05$) only in one lot on the medium level of D.C.P. and in two lots on the high level. No response was obtained from the higher energy intake on the low D.C.P. rations.

The above results indicate, as has been pointed out previously (3, 17), that the protein utilization of the ruminant animal is dependent upon the energy content of the ration.

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CHLORTETRACYCLINE AND PROTEIN LEVEL IN RATIONS FOR MARKET HOGS

I. EFFECT ON RATE OF GAIN AND EFFICIENCY OF FEED UTILIZATION[1]

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ABSTRACT

A study was made of the effect of protein level and chlortetracycline (aureomycin) supplementation on rate of gain and feed efficiency of market hogs, self-fed from weaning to market weight. Four different levels of protein (i.e., approximately 13, 15, 17 and 19 per cent from weaning to 70 lb.; approximately 12, 13.5, 14.5 and 15.5 per cent from 70 to 130 lb.; and approximately 11, 12, 12.5 and 13 per cent from 130 to 200 lb.;) with and without chlortetracycline were used.

For the over-all feeding period (i.e. from weaning to market weight) the addition of aureomycin caused statistically significant increases in rate of gain at all protein levels. Protein level also affected rate of gain significantly. The effect of the "Protein × Antibiotic" interaction on rate of gain was found to be significant.

Aureomycin improved feed efficiency at all protein levels, significantly so at the low and medium levels. Protein level had no significant effect on feed efficiency for the feeding period as a whole.

Aureomycin significantly increased over-all feed consumption at the standard protein level only. Protein level significantly influenced feed consumption. The effect of the "Protein × Antibiotic" interaction on feed consumption was significant.

INTRODUCTION AND REVIEW OF LITERATURE

Protein constitutes one of the most expensive and important ingredients of swine rations. For economical pork production, it is necessary that swine receive the minimum amount of protein which will permit optimum growth rates and feed efficiency. Keith and Miller (11, 12), Mitchell (15), Crampton and Ashton (6), Ferrin (8) and others have investigated the protein levels required for optimum gain at various stages of growth. With the introduction of antibiotics in swine nutrition and the generally observed increases in rate of gain and feed efficiency resulting from their use [Luecke *et al.* (13), Brown and Luther (3), Catron *et al.* (4), Bowland *et al.* (2), and others], came investigations to determine whether the feeding of antibiotics would make it possible to reduce protein levels and still allow for good growth and feed efficiency.

Cunha *et al.* (7), Catron *et al.* (5), Robinson (17), and Meade (14) provide evidence that antibiotics may exert a protein sparing effect, but Hoefer *et al.* (9) found that terramycin did not seem to affect the protein requirements of pigs under the conditions of their test.

More recently, Jensen *et al.* (10), feeding corn-soybean type rations containing from 10 to 20 per cent protein, with and without two kinds of antibiotics, concluded that protein level significantly affected rate of gain and that a level of 16 to 18 per cent protein without antibiotics and 14

[1]Contribution from Division of Animal and Poultry Science, Experimental Farms Service, Canada Department of Agriculture.

per cent with antibiotics gave the fastest gains. Protein levels were held constant throughout the test. Antibiotic supplementation did not produce similar results in the two tests reported.

In the present study, feeds common in Western Canada were used, and protein levels were adjusted as the pigs increased in weight.

MATERIALS AND METHODS

Three consecutive trials, each involving eight lots of purebred Yorkshire pigs, comprised this experiment. In two trials, seven pigs made up each lot; in the third, six. Within each trial, all lots were balanced according to litter, sex, and total weight. All pigs had uniform treatment prior to going on experiment and averaged 35 pounds at 8 weeks of age when placed on test.

Feed and water were available *ad libitum*. Pigs were confined indoors during the entire feeding period. They were weighed individually and feed consumption was determined for each lot each week. Each lot of pigs was changed from a "growing" to an "intermediate" ration when the

TABLE 1.—COMPOSITION OF RATIONS[1] (PER CENT)

Period	Ingredient	Low protein	Medium protein	Standard protein	High protein
Weaning to 70 lb.	Hulless oats	47.5	44.1	39.5	35.3
	Barley	47.5	44.1	39.5	35.3
	Meat meal	1.0	4.0	7.9	12.0
	Linseed oil meal	—	4.0	7.9	11.0
	Alfalfa meal	—	2.0	4.7	5.9
	Bonemeal	3.5	1.3	—	—
	Iodized salt	.5	.5	.5	.5
	Crude Protein (%)	13.4	15.3	17.3	19.1
70 lb. to 130 lb.	Oats	30.1	30.0	27.7	26.0
	Barley	64.0	59.0	57.5	55.7
	Meat meal	2.3	4.8	6.6	8.0
	Linseed oil meal	1.5	4.1	5.5	7.0
	Alfalfa meal	.6	1.1	2.2	2.8
	Limestone	1.0	.5	—	—
	Iodized salt	.5	.5	.5	.5
	Crude Protein (%)	12.2	13.6	14.5	15.3
130 lb. to 200 lb.	Oats	39.1	37.8	36.8	36.1
	Barley	59.0	57.8	56.1	55.7
	Meat meal	—	1.6	3.2	4.0
	Linseed oil meal	—	.8	1.6	2.0
	Alfalfa meal	—	.5	1.0	1.4
	Bonemeal	.8	—	—	—
	Limestone	.6	1.0	.8	.3
	Iodized salt	.5	.5	.5	.5
	Crude Protein (%)	11.2	11.9	12.6	13.0

[1]A vitamin feeding oil containing 1,000 I.U. of vitamin A and 150 I.U. of vitamin D per gram was fed at the rate of 3½, 2 and 0 lb. per ton of feed during the growing, intermediate and finishing periods respectively.

TABLE 2.—SUMMARY OF RATE OF GAIN AND FEED CONSUMPTION DATA
(Average of three trials)

PROTEIN LEVEL	Low protein		Medium protein		Standard protein		High protein		Necessary difference ....lb.	
	Control	Aureomycin	Control	Aureomycin	Control	Aureomycin	Control	Aureomycin	P = .05	P = .01
No. of pigs fed	20	20	20	20	20	20	20	20		
Av. initial weight (lb.)	35	35	35	35	35	35	35	35		
Av. final weight (lb.)	200	200	199	200	201	201	202	200		
Weaning to 70 lb.	*13.4% Protein*		*15.3% Protein*		*17.3% Protein*		*19.1% Protein*			
Av. daily gain (lb.)	.80	.87	.81	.97	.84	1.09	.87	.95	.12	.15
Av. daily feed (lb.)	3.10	3.25	3.05	3.18	2.98	3.45	3.17	3.45	—	—
Feed required/lb. gain (lb.)	3.94	3.68	3.79	3.32	3.79	3.19	3.68	3.66	.58	.71
70 lb. to 130 lb.	*12.2% Protein*		*13.6% Protein*		*14.5% Protein*		*15.3% Protein*			
Av. daily gain (lb.)	1.47	1.54	1.51	1.70	1.66	1.73	1.63	1.71	.14	.17
Av. daily feed (lb.)	6.36	6.18	5.80	5.91	5.86	6.26	6.15	6.09	—	—
Feed required/lb. gain (lb.)	4.33	3.97	3.89	3.49	3.57	3.63	3.77	3.59	.44	.54
130 lb. to 200 lb.	*11.2% Protein*		*11.9% Protein*		*12.6% Protein*		*13.0% Protein*			
Av. daily gain (lb.)	1.65	1.87	1.49	1.61	1.44	1.72	1.81	1.88	.20	.24
Av. daily feed (lb.)	7.94	8.07	7.29	7.48	6.89	7.89	8.39	8.28	.62	.76
Feed required/lb. gain (lb.)	4.80	4.33	4.93	4.65	4.81	4.56	4.66	4.45	.58	.71
Summary (weaning to 200 lb.)										
Av. daily gain (lb.)	1.29	1.40	1.26	1.41	1.27	1.50	1.41	1.48	.07	.09
Av. daily feed (lb.)	5.75	5.70	5.38	5.54	5.22	5.89	5.83	5.87	.32	.39
Feed required/lb. gain (lb.)	4.45	4.06	4.27	3.93	4.11	3.92	4.13	3.96	.27	.34

pigs averaged 70 pounds and to a "finishing" ration when the pigs averaged 130 pounds. Each pig was marketed individually at as close to 200 pounds in weight as possible.

Eight treatments, i.e., four levels of protein with, and without chlortetracycline (aureomycin), were used. Aureomycin was added to the growing ration at the rate of 9 milligrams per pound of feed and to the intermediate and finishing rations at the rate of $4\frac{1}{2}$ milligrams per pound.

Table 1 shows the rations fed, and the actual total crude protein content as determined by analysis.

Rate of gain, feed efficiency, and feed consumption data were subjected to an analysis of variance according to the method of Snedecor (18). Because "Protein × Replicate" and "Antibiotic × Replicate" interactions proved to be non-significant for all comparisons when tested against the P×A×R (error) with 6 degrees of freedom, they were combined with the P×A×R to provide an estimate of error with 14 degrees of freedom, which is used in the analysis presented in Table 3. Where significant F values occurred, L.S.D.'s were calculated and used in the discussion to compare the treatment means.

The effects of protein level and aureomycin supplementation on carcass quality are reported separately (1).

RESULTS AND DISCUSSION

Table 2 summarizes the rate of gain, feed consumption, and feed efficiency data by sub-period and for the total period.

Aureomycin caused some increases in rate of gain at all protein levels during all three sub-periods. While results were variable, statistically significant increases in rate of gain occurred at all protein levels, except the high level, during one or more of the three sub-periods.

Protein level had a statistically significant effect on rate of gain during all three sub-periods and for the total feeding period (Table 3). The effect of protein level on rate of gain was, however, not consistent between feeding periods. During the growing and intermediate periods the tendency was for the higher protein levels to cause faster rates of gain (Table 2). However, during the finishing period the faster rates of gain occurred at the low and high protein levels. Thus, for the feeding period as a whole, there was some "evening up" of rates of gain as far as the effect of protein level was concerned. When no aureomycin was fed, rates of gain were similar at the low, medium and standard levels and significantly higher ($P<.01$) at the high protein level. Where aureomycin was fed, rates of gain were similar at the low and medium protein levels and significantly higher at the standard ($P<.01$) and high ($P<.05$) protein levels. The effect of the "Protein × Antibiotic" interaction on rate of gain was significant ($P<.05$).

Analysis of variance (Table 3) revealed that aureomycin had a significant effect on feed efficiency during all three sub-periods and for the total period. Table 2 suggests that the greatest improvement in feed efficiency occurred at progressively lower levels of protein as the pigs

TABLE 3.—ANALYSIS OF VARIANCE SHOWING MEAN SQUARES FOR RATE OF GAIN, FEED EFFICIENCY AND FEED CONSUMPTION OF HOGS FED FOUR LEVELS OF PROTEIN, WITH AND WITHOUT AUREOMYCIN

Source of variation	Degrees of freedom	Weaning to 70 lb.			70–130 lb.			130–200 lb.			Weaning to 200 lb.		
		Rate of gain	Feed efficiency	Feed consumption	Rate of gain	Feed efficiency	Feed consumption	Rate of gain	Feed efficiency	Feed consumption	Rate of gain	Feed efficiency	Feed consumption
Antibiotic	1	.1190[+]	.6936*	.3174	.0737[+]	.2992*	.0301	.1838[+]	.5310*	.4988	.1190[+]	.4510[+]	.2562*
Protein level	3	.0177*	.1161	.0486	.0384[+]	.3728[+]	.1803	.1190[+]	.0732	1.3786[+]	.0147[+]	.0680	.1767*
Replicate (season)	2	.2055[+]	3.2065[+]	.3892*	.0831[+]	1.4108[+]	.8926[+]	.0608*	.8014[+]	.1381	.0750[+]	.0129	1.6840[+]
Protein × Antibiotic	3	.0103	.0980	.0534	.0050	.0654	.0944	.0141	.0204	.3142	.0072*	.0179	.1550*
Error	14	.0048	.1190	.0898	.0061	.0638	.0911	.0131	.1094	.1249	.0018	.0245	.0338
Total	23												

*P ≥ .05
[+]P < .01

TABLE 4.—CALCULATED AVERAGE DAILY CRUDE PROTEIN CONSUMPTION PER PIG (POUNDS)

Period	Low protein		Medium protein		Standard protein		High protein	
	Control	Aureomycin	Control	Aureomycin	Control	Aureomycin	Control	Aureomycin
Growing 35–70 lb.	.42	.44	.47	.49	.52	.62	.61	.66
Intermediate 70–130 lb.	.78	.75	.79	.80	.85	.92	.94	.93
Finishing 130–200 lb.	.89	.90	.87	.89	.87	.99	1.09	1.08

grew, i.e., the pounds of feed saved per pound of gain, due to aureomycin supplementation, were greatest at the standard, medium and low levels of protein during the growing, intermediate and finishing periods respectively.

Protein level had a significant effect on feed efficiency only during the intermediate period (Table 3), when the pigs fed the low protein ration required significantly more feed to put on a pound of gain than did those fed some of the other levels of protein (Table 2).

Antibiotic supplementation had no significant effect on level of feed consumption within any one feeding period. However, for the over-all period of the test, its effect on feed intake was significant ($P < .05$). Table 2 shows that aureomycin increased feed intake (13 per cent) at the standard protein level and that its effect on feed intake at the other protein levels was negligible. The "Protein × Antibiotic" interaction (Table 3) proved to be statistically significant (P .05).

The effect of protein level on feed consumption was significant during the finishing period ($P < .01$) (Table 3), when pigs fed medium and standard protein rations without aureomycin consumed significantly less feed per day ($P < .05$ and $P < .01$ respectively) than did the pigs fed low or high protein rations without aureomycin (Table 2). For the over-all period the trend was similar to that found for the finishing period but the differences were significant only at the 5 per cent level. The effect of the "Protein × Antibiotic" interaction on feed consumption was also significant ($P < .05$) for the total period (Table 3).

That aureomycin caused highly significant increases in rate of gain and significant increases in feed efficiency in all three sub-periods, without accompanying significant increases in feed intake (Table 3) indicates that aureomycin improved feed efficiency by some mechanism(s) other than by simply increasing feed intake. [This is particularly apparent at the low protein level. At the standard protein level increased feed intake (Table 2) could have been at least partially responsible for the increased efficiency].

If we consider feed efficiency to be a measure of the ration's ability to meet the pigs' nutrient requirements (including protein), and if we select the most efficient ration (regardless of the statistical significance of differences between protein levels), we should select rations of the following protein levels for the three growth periods:

	Without Aureomycin	*With* Aureomycin
Weaning to 70 lb.	19.1 (high)	17.3 (standard)
70 to 130 lb.	14.5 (standard)	13.6 (medium)
130 to 200 lb.	13.0 (high)	11.2 (low)

The performance of pigs fed the aureomycin rations (above) was equal to or superior to the performance of the pigs fed the rations of higher protein content without aureomycin, listed opposite. While this demonstrates the "protein-sparing" effect of aureomycin we cannot conclude that these are the best levels of protein to feed during the various periods. The protein level fed in one period may have a bearing on the most satisfactory level to feed during the next period.

The important finding in this experiment is the good performance made by pigs fed the low level protein rations plus aureomycin. The fact that their rate of gain and efficiency of feed utilization equalled that of pigs fed the high protein rations without aureomycin is of economic importance considering the relative cost of the two rations.

The rapid rate of gain made during the finishing period by the pigs fed the low protein rations with aureomycin was due in part to their high feed consumption. Both low-protein lots (i.e., with and without aureomycin) actually consumed slightly more protein per day than did the corresponding medium-protein lots. The calculated average daily protein consumption per pig by lot and period is shown in Table 4.

The recommended (16) average daily crude protein requirement per pig is .52, .74, and .89 pounds for pigs averaging 53, 100, and 165 pounds respectively (the mid-points in the weight ranges corresponding to the feeding periods in this test). Therefore, with the exception of the growing period, all pigs consumed very close to, or over, the recommended daily minimum requirement of protein.

The data of Tables 2 and 4 would indicate that, in this experiment, protein consumption and rate of gain are more closely related to the protein level of the ration during the growing period than during the finishing period. In the finishing period it is demonstrated that the pigs fed the low protein rations were able to meet their protein requirements (at least quantitatively) by increasing their feed intake. Their rate of gain compared favourably with that of the pigs fed the standard protein ration (especially when no aureomycin was fed) and even though their feed efficiency (pounds of feed per pound of liveweight gain) was somewhat poorer, the relative cost of the rations was such that the pigs fed the low protein ration plus aureomycin gained more economically.

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CHLORTETRACYCLINE AND PROTEIN LEVEL IN RATIONS FOR MARKET HOGS

II. EFFECT ON CARCASS QUALITY[1]

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ABSTRACT

Three trials, with a total of 20 pigs on each of eight treatments, were conducted to determine the effect, on carcass quality of Yorkshire pigs, of self-feeding rations of low, medium, standard, and high protein content, with and without chlortetracycline (aureomycin), from weaning to market weight. The approximate protein levels were 13, 15, 17, and 19 per cent from weaning to 70 lb.; 12, 13.5, 14.5, and 15.5 per cent from 70 to 130 lb.; and 11, 12, 12.5, and 13 per cent from 130 to 200 lb.

Aureomycin had no significant effect on length of carcass, or on the area of the eye of lean, at any of the four levels of protein tested. Aureomycin significantly increased the depth of backfat, but not shoulder or loin fat, at all protein levels. With the type of pigs used this increase did not have any adverse effect on grades.

Protein level had no significant effect on length of carcass, depth of shoulder fat, or depth of backfat. As protein level increased, increases in the area of the eye of lean occurred.

INTRODUCTION AND REVIEW OF LITERATURE

The thickness of backfat on bacon hogs is one of the most important factors determining carcass grade in Canada and any factor which might cause an increase in backfat thickness needs consideration. There is some evidence that antibiotics in swine rations indirectly cause an increase in backfat thickness.

Vestal (9) and Bowland *et al.* (2) reported that hogs fed aureomycin had thicker backfat than those not fed aureomycin. Beacom[2] reported less definite effects in trials with different levels of each of three kinds of antibiotics.

Some investigators have fed antibiotics during the first stages of the pig's growth (to approximately 125 pounds) and then eliminated them from the finishing ration. Vestal (10) found that in this way aureomycin-fed hogs slaughtered at 224 pounds showed only slightly increased backfat thickness over control pigs. Bowland and McElroy (3) also found no adverse effect on carcass quality when antibiotic feeding was stopped at 75 or 125 pounds.

Terrill *et al.* (8) feeding streptomycin, and Heidebrecht *et al.* (4) feeding penicillin, found no adverse effect on carcass quality due to antibiotic supplementation of the ration during the later stages of growth.

Wallace *et al.* (11) found that the removal of an antibiotic from rations of growing-fattening swine resulted in a significant slowing of gains and a reduction in feed efficiency, while a reduction of 50 per cent in aureomycin did not seriously interfere with the pig's performance.

[1] Contribution from Division of Animal and Poultry Science, Experimental Farms Service, Canada Department of Agriculture.

[2] Beacom, S. E. Animal Husbandry Annual Reports. Can. Dept. Agr. Experimental Farms Service, Melfort, Sask., 1953, 1954, and 1955.

Robinson *et al.* (6) found that increasing the protein content of the ration increased the percentage of primal and lean cuts while backfat thickness decreased. Wilson *et al.* (12) found that pigs receiving rations of higher protein content produced leaner carcasses. At the high protein level (18 per cent) the addition of aureomycin alone or in combination with vitamin B_{12} did not increase carcass leanness. However, the addition of aureomycin to rations of medium and low protein content resulted in increased leanness.

The purpose of the experiment reported here was to determine the effects of protein level and chlortetracycline (aureomycin) supplementation on the carcass quality of purebred Yorkshire market hogs fed rations composed of typical Western Canada feeds.

MATERIALS AND METHODS

Rations based on oats and barley and fortified with minerals and vitamins were supplemented with varying amounts of meat meal and linseed oil meal, to give crude protein levels (per cent) as follows:

	Low	Medium	Standard	High
Weaning to 70 lb.	13.4	15.3	17.3	19.1
70 to 130 lb.	12.2	13.6	14.5	15.3
130 to 200 lb.	11.2	11.9	12.6	13.0

Each protein level was fed with and without aureomycin. The ration formulae and other details of the experiment have been reported (1).

All pigs were marketed individually upon reaching a weight of 200 pounds or as close to this weight as was possible. In addition to receiving a commercial grade, all carcasses were measured for length, backfat thickness, balance, and area of loin according to A.R. Standards (5) by the officers of the Production Service of the Canada Department of Agriculture.

Analysis of variance was carried out on the carcass data according to the method of Snedecor (7).

RESULTS AND DISCUSSION

Effects on Carcass Quality

The results of the various treatments on carcass characteristics are presented in Table 1. In order that comparisons may be made between rates of gain and carcass characteristics, the over-all average daily gain and feed efficiency figures are given at the bottom of the table. Differences necessary for statistical significance at $P = .05$ and $P = .01$ are shown for the more important carcass characteristics.

The data show that the length of carcass was unaffected by either protein level or aureomycin supplementation. Depth of shoulder, back, and loin fat was not significantly affected by protein level of the ration. While not significantly affecting depth of either shoulder or loin fat aureo-

TABLE 1.— THE EFFECT OF PROTEIN LEVEL AND AUREOMYCIN SUPPLEMENTATION ON CARCASS QUALITY OF MARKET HOGS

Treatment	Low protein	Low protein + Aureomycin	Medium protein	Medium protein + Aureomycin	Standard protein	Standard protein + Aureomycin	High protein	High protein + Aureomycin	Necessary difference	
									P = .05	P = .01
Number of carcasses	20	20	20	20	20	20	20	19*		
Av. final liveweight (lb.)	200	200	199	200	201	201	202	200		
Hot dressed weight (lb.)	152	153	153	154	153	154	153	154		
Dressing percentage	76.0	76.5	76.9	77.0	76.1	76.6	75.7	77.0		
Av. length of side (in.)	31.1	30.8	31.3	31.0	31.2	31.1	31.0	30.9		
Depth of backfat (in.)										
Shoulder	1.69	1.68	1.59	1.71	1.66	1.69	1.65	1.69		
Back	.76	.83	.74	.84	.73	.80	.77	.84	.07	.09
Loin	1.35	1.31	1.25	1.32	1.23	1.36	1.34	1.33		
Total ("Fat Index")	3.80	3.82	3.58	3.87	3.62	3.85	3.76	3.86	.20	.25
Area of eye of lean (sq. in.)	3.21	3.37	3.63	3.56	3.76	3.62	3.76	3.71	.23	.28
Hams (% of cuts)	25.0	24.6	25.2	25.1	25.2	25.2	25.2	24.9		
Market Grade										
A	14	16	19	13	16	15	18	16		
B_1	6	4	1	7	4	5	2	3		
Over-all av. daily gain (lb.)	1.29	1.40	1.26	1.41	1.27	1.50	1.41	1.48		
Over-all feed req'd/lb. gain (lb.)	4.45	4.06	4.27	3.93	4.11	3.92	4.13	3.96		

* One barrow died during shipment.

mycin did significantly (and consistently) increase the depth of back fat at all protein levels tested. However, with the type of pigs used in this experiment, this increase (about 9 per cent) was not sufficient to have any adverse effect on grades.

Protein level was found to have a highly significant effect on the cross-sectional area of the "eye" of lean. On aureomycin supplemented rations areas of loin were 3.37, 3.56, 3.62 and 3.71 square inches, for carcasses of pigs fed the low, medium, standard, and high protein rations respectively. "Standard" and "high" carcasses had significantly greater loin area than the "low" carcasses, while the difference between "low" and "medium" carcasses approached significance.

Corresponding loin areas on the carcasses of pigs fed no aureomycin were 3.21, 3.63, 3.76 and 3.76 square inches. "Medium", "standard", and "high" carcasses did not differ significantly from each other in area of loin, but all were significantly greater than the "low protein" carcasses.

The data show that increasing protein level produced leaner carcasses, but the addition of aureomycin at any of the protein levels tested did not result in leaner carcasses. These results do not agree entirely with the findings of Wilson *et al.* (12), but the low protein ration (13.4-12.1-11.2) in this experiment would average somewhat higher in protein content than the lowest protein ration (14-11-9.5) used by Wilson.

Under the economic conditions existing during these experiments the use of aureomycin resulted in greater net market returns per pig at all protein levels. The greatest net returns per pig were from pigs fed the low protein ration plus aureomycin.

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RAPESEED OIL MEAL AS A PROTEIN SUPPLEMENT FOR SWINE AND RATS

I. RATE OF GAIN, EFFICIENCY OF FOOD UTILIZATION, CARCASS CHARACTERISTICS AND THYROID ACTIVITY[1,2]

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ABSTRACT

Diets containing 0, 2 or 10 per cent expeller extracted Argentine type rapeseed oil meal were fed to swine from 3 weeks of age to market weight averaging 195 lb., and to albino rats from 3 weeks to 6 months of age. The 10 per cent level of the meal depressed the rate of liveweight gain and in some cases reduced efficiency of food utilization in both species. Food consumption was not adversely influenced by the levels of meal used in these diets. Total weight, histological sectioning and I^{131} turnover rate of the thyroid gland indicated hypertrophy and other abnormalities of the gland in the animals fed 10 per cent meal. The 2 per cent level of meal did not exert consistent effects on the criteria measured. Female rats were more susceptible than males to the effects of the meal on rate of gain, but ovariectomy of females appeared to reduce this susceptibility. The nutritional quality of the diet fed to rats tended to alter the response to toxicity of the meal. Swine carcass characteristics were not markedly affected by rapeseed oil meal in the ration.

INTRODUCTION

Rapeseed oil meal[4], a by-product left after the extraction of oil from the seed of the rape plant, *Brassica napus*, L., has increased in availability in Western Canada as the acreage sown to the crop has risen steadily in recent years. In 1955, Bell (4) prepared an extensive review concerning the nutritional status of ROM. This article pointed out that the feeding of rapeseed oil meal has been reported to result in various disturbances such as thyroidal hyperplasia, reduced growth, appetite depression and liver and kidney enlargements.

ROM has been reported to contain a number of toxic substances (4) at least one of which, 1–5-vinyl-2-thiooxazolidone, causes thyrotoxicity (3). Renner *et al.* (19) noted that the Argentine type of rapeseed, which is most widely produced in Western Canada, exhibited a greater goitrogenic effect than did the Polish type. This observation is in contrast to that of Bell (5) who reported no differences in thyroid response when Argentine or Polish types of ROM were fed, even though the former contained a higher level of goitrogen.

Results such as those of Seale at Manitoba with swine as reported by Bell (4), Thomasson and Boldingh (21) with rats, and Klain *et al.* (13) with chicks indicate that as the percentage ROM in a diet is increased the rate of gain is decreased. Dow and Allen (10), 1954, reported that in a 19 per cent protein ration for broilers ROM was a satisfactory substitute for soybean oil meal. There is a suggestion from the results of most experi-

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[3]Adapted from a thesis submitted in partial fulfilment of the requirements for a M.Sc. degree.
[4]For brevity, the abbreviation "ROM" is used subsequently.

ments that the nutritional qualities of ROM are not parallel to its potential based on an average analysis of 33.5 per cent crude protein, 8.1 per cent fat and 10.8 per cent crude fibre [Morrison (17)].

Variation in the source of the sample of ROM as well as species and sex variability in test animals may account for some of the discrepancies in results reported. For example, Bell and Williams (7) obtained results with mice fed ROM-supplemented diets which deviated from results with some other species. There is contradictory evidence as to which sex is most affected by goitrogens (4). The normal thyroid gland in the female, however, frequently appears to be at a higher level of activity than that of the male and consequently the female gland is more susceptible to antithyroidal drugs as reported, for example, by Eskin and Bogdanone (11), and Marine and Baumann (15).

This paper reports on a series of experiments with swine fed 0, 2 or 10 per cent Argentine type ROM from 3 weeks of age to market weight, and on experiments with 3-weeks- to 6-months-old albino rats fed the same diets. A study was made of liveweight gain, food intake, efficiency of food utilization, carcass characteristics and thyroid activity.

TABLE 1.—DIETS USED FOR EXPERIMENTAL ANIMALS

Ration ingredients	Starter	Grower	Finisher
	%	%	%
Wheat	73.45	25.0	25.0
Barley	0	46.9	36.85
Oats	0	10.0	25.0
Sucrose	10.0	0	0
Soybean oil meal	11.0	12.8	8.0
Fishmeal	4.0	2.0	2.0
Alfalfa meal (dehydrated)	0	2.0	2.0
Iodized salt	0.50	0.50	0.50
Ground limestone	0.50	0.50	0.50
Zinc sulphate	0.05	0.05	0.05
Antibiotic supplement[1]	0.20	0.20	0.10
Vitamin supplement[2]	0.30	0.05	0
Argentine rapeseed oil meal[3]			
Crude protein	Av. % 18.4	16.9	14.2

[1]Containing 5 gm. oxytetracycline (terramycin) and 5 gm. chlortetracycline (aureomycin) per pound

[2]The supplemental vitamins supplied per cwt. of feed during the starter period were:

Vitamin A	50,000 I.U.
Vitamin D_2	10,000 I.U.
Niacin	1.8 gm.
Choline	2.0 gm.
Riboflavin	400 mg.
Pantothenic acid	800 mg.
Folic acid	12 mg.
Vitamin B_{12}	900 micrograms

Vitamins A and D_2 were continued at 1/2 this level in the growing and finishing period, while all other vitamins except vitamin B_{12} were added at 1/4 this level in the growing period and discontinued in the finishing period. Vitamin B_{12} was removed in both the growing and finishing period.

[3] 2% ROM replaced 0.4% of wheat and 1.6% of SOM for ration No. 2.
10% ROM replaced 2.0% of wheat and 8.0% of SOM for ration No. 3.

MATERIALS AND METHODS

Diet Formulation

The composition of the starter, grower and finisher rations fed in these experiments is shown in Table 1. The starter rations were fed to pigs from approximately 13 to 35 pounds liveweight, the grower rations from 35 to 110 pounds, and the finisher rations from 110 pounds to market weight. The rats received the same diets as were fed to the pigs but in all cases were allotted to a particular diet, i.e. 2 per cent ROM starter, and fed this throughout the trials. Diets for the rats were ground to pass a 2-mm.-mesh screen to prevent sorting.

The starter diets contained 18.4 per cent, the grower diets 16.9 per cent and the finisher diets 14.2 per cent total protein at each of the 0, 2 and 10 per cent levels of ROM. The Argentine type ROM used in these experiments was an expeller extracted meal and contained 37.6 per cent protein (N x 6.25). It was added to the diets at the expense of solvent extracted soybean oil meal and wheat, with 2.0 pounds ROM replacing 1.6 pounds soybean oil meal and 0.4 pounds wheat.

Swine Experiments

In the experiment in which group feeding was employed, 24 pigs, 12 of each sex, were divided uniformly on the basis of weight and sex into three ration groups. Three pigs in each group were of Lacombe x Yorkshire breeding and five of pure Yorkshire breeding. The pigs were fed in two replicates starting in April of 1957 with feed being supplied in self-feeders.

In the experiment in which individual feeding was employed 12 male pigs were allotted in groups of 4 to the three rations. These pigs were of Tamworth x Lacombe-Yorkshire, Lacombe x Yorkshire, and pure Yorkshire background, and were allotted on a litter-mate basis to each ration and started on trial in groups of 6 in June and August, 1957. The pigs were fed individually three times daily at 8 a.m., 12 p.m. and 5 p.m., being confined for a period of 1 hour at each feeding, but were together when not being fed.

All pigs were weaned at 21 days of age. Following allotment they were fed a cadmium oxide compound for ascarid removal. The pigs in each experiment were fed: (1) a basal ration with no ROM; (2) a ration with 2 per cent Argentine type ROM; and (3) a ration with 10 per cent Argentine type ROM. Males were castrated at under 6 weeks of age. The pigs were marketed at the first weekly weighing after they reached 190 pounds liveweight and Canadian Advanced Registry (2) measurements and scores were obtained.

The thyroid glands were removed from the 12 individually-fed pigs just before they reached the eviscerating table and 20 to 35 minutes after the jugular vein was severed. Random portions of the gland were immediately immersed in Bouin's fluid to fix the gland in preparation for staining with hematoxalin and eosin for microscopial study and photography. The remainder of the gland was placed in a small covered glass bottle and the gland in the two bottles was weighed.

TABLE 2.—RATE OF GAIN, FEED INTAKE, FEED EFFICIENCY, CARCASS CHARACTERISTICS AND THYROID WEIGHT OF PIGS FED ROM-CONTAINING RATIONS

Method of feeding		Group							Individual			
Ration		Basal	2% ROM	10% ROM					Basal	2% ROM	10% ROM	
Sex						Male	Female					
No. pigs		8	8	8		12	12		4	4	4	
Av. age on test	days	26	26	26		25	27		21	21	21	
Av. age to market	days	149	154	166	*	149	163	**	164	169	182	*
Growth Data												
Starter period (13–35 lb.):												
Av. daily gain	lb.	0.72	0.65	0.64	n.s.	0.68	0.64	n.s.	0.56	0.56	0.43	**
Av. daily feed	lb.	1.46	1.38	1.52					1.26	1.27	1.15	n.s.
Feed per lb. gain	lb.	2.03	2.11	2.37					2.25	2.28	2.70	n.s.
Growing period (35–110 lb.):												
Av. daily gain	lb.	1.65	1.55	1.51	n.s.	1.65	1.50	*	1.49	1.40	1.26	n.s.
Av. daily feed	lb.	4.63	4.43	4.81					3.67	3.52	3.60	n.s.
Feed per lb. gain	lb.	2.81	2.85	3.19					2.47	2.51	2.84	n.s.
Finishing period (110-195 lb.):												
Av. daily gain	lb.	1.86	1.80	1.62	**	1.88	1.71	**	1.61	1.52	1.47	n.s.
Av. daily feed	lb.	6.85	6.90	6.71					5.56	5.82	5.89	*
Feed per lb. gain	lb.	3.69	3.83	4.15					3.45	3.84	4.02	n.s.
Summary (13–195 lb.):												
Av. daily gain	lb.	1.49	1.43	1.32	**	1.47	1.38	**	1.29	1.23	1.11	*
Av. daily feed	lb.	4.63	4.65	4.66					3.74	3.83	3.82	n.s.
Feed per lb. gain	lb.	3.11	3.24	3.54					2.91	3.11	3.42	n.s.
Carcass Data												
Av. hot carcass weight	lb.	154.4	153.1	154.3	n.s.	152.6	155.1	n.s.	154.0	155.0	149.8	n.s.
Dressing	%	79.2	78.4	78.3	n.s.	78.4	78.8	n.s.	78.3	79.2	77.8	n.s.
Av. length	in.	30.3	30.5	30.0	n.s.	30.3	30.2	n.s.	31.3	31.1	30.3	n.s.
Av. backfat (3 measurements)	in.	1.63	1.48	1.52	n.s.	1.61	1.48	*	1.43	1.42	1.53	n.s.
Av. loin area	sq. in.	3.07	3.32	3.17	n.s.	3.06	3.31	n.s.	3.85	3.73	3.20	*
Total A.R. score	%	49	64	51	n.s.	51	57	n.s.	79	79	61	n.s.
Thyroid Data												
Liveweight	kg.								89.5	89.0	87.5	n.s.
Thyroid weight	gm.								5.9	6.6	17.3	**
Body weight (gm.) Thyroid weight (mg.)									17.0	14.5	5.2	*

In this table and subsequent tables the following symbols indicate significant levels: *Significant at $P < 0.05$ **Significant at $P < 0.01$ n.s. Non-significant

Rat Experiments

Weanling albino rats of the Sprague-Dawley strain were fed for a period of 148 days on each of the nine diets used for the pig studies, i.e. 3 starter, 3 grower, and 3 finisher rations, containing 0, 2 or 10 per cent Argentine type ROM. At the conclusion of this period the 27 rats were utilized for I^{131} uptake studies.

A solution of 75 microcuries of a carrier-free sodium salt of I^{131} in 0.5 ml. of distilled water was injected intraperitoneally into each rat and the animal killed 10 hours later. The rat was anaesthetized with chloroform, the thyroid gland dissected out and immediately weighed in a ground glass stoppered bottle. The gland was placed in a pyrex test tube and 2 ml. of 1N NaOH added. The tube was then placed in warm water to facilitate dissolving the glandular material.

A blood sample was drawn from each anaesthetized rat by puncturing the heart and collecting the blood in a B-D Vacutainer collecting tube containing potassium oxalate. The blood was centrifuged, 1 ml. of serum obtained and the serum proteins, containing the protein bound iodine, "PBI", were precipitated by the addition of 10 ml. of cold 10 per cent trichloroacetic acid. The precipitated serum was centrifuged in a conical tube and rewashed twice with 5 ml. of cold 5 per cent trichloroacetic acid, following which the coagulum was redissolved with 2 ml. 1N NaOH and transferred to a pyrex test tube. Aliquots were made and the counts per minute recorded using a well-type gamma counter*.

In a second experiment, designed to study the effects of ROM on castrated male and female rats, 4 intact males and females, plus 5 castrate males and 5 ovariectomized females, were fed the swine grower ration containing 10 per cent Argentine type ROM. Following a 95-day experimental period, the animals were weighed, given an overdose of chloroform, and weights and other data obtained on a number of organs.

Analyses of variance were conducted on the data with the error mean square being used as the denominator for calculating F values. Where the design permitted, the ration (starter, grower, finisher) treatment (level of ROM), and sex as well as the interactions between these factors were included in the analyses. Statistical results are presented only where significance was obtained in some factor.

RESULTS AND DISCUSSION

Swine Gains, Feed Efficiency and Carcass Characteristics

Rate of liveweight gain, feed intake, efficiency of feed utilization and carcass characteristics of both the group-fed and individually-fed pigs are listed in Table 2.

As the level of ROM in the ration rose the daily weight gain decreased and the age to market increased, with an average difference in market age of 17 to 18 days between the basal and 10 per cent ROM-fed animals.

*A Tracerlab Deca Scaler was used to record counts per minute detected by a Scintillator manufactured by Atomic Instrument Co., Cambridge, Mass.

The average daily feed intake remained relatively constant as the level of ROM increased except in the finishing period of the individually-fed pigs where pigs receiving ROM ate more than those on the basal ration. This observation does not agree with some reported results as reviewed by Bell (4) which indicated appetite depression when ROM was fed. Bowland (9) noted that when an alternate ration was available, pigs did not accept a pre-starter ration containing the same ROM as was used in the present study. The data in Table 2 indicate that pigs will eat normal levels of rations containing 10 per cent Argentine type ROM.

Efficiency of feed utilization decreased as the level of ROM in the ration increased. The differences were not significant in the individually-fed pigs and could not be analysed in the group-fed pigs.

The addition of 2 or 10 per cent ROM to the ration had a limited effect on carcass characteristics as measured by the criteria listed in Table 2. The only significant change was a reduction in loin area in individually-fed pigs receiving 10 per cent ROM as compared with pigs fed the other two rations. There was a trend toward shorter carcasses from the pigs receiving 10 per cent ROM even though these pigs were older at slaughter and would be expected to have longer carcasses than the younger pigs fed 0 or 2 per cent ROM in their rations. It is of interest that thiouracil-fed hogs have shorter carcasses than control animals (8, 18), and the trend toward shortened carcasses in the ROM-fed pigs may be a reflection of growth retardation resulting from thyroid changes which are discussed later in this paper.

There were differences in certain traits between sexes and strains but sex and strain differences in response to ROM were not evident.

Swine Thyroid Glands

The data at the bottom of Table 2 show that, as the levels of ROM were increased in the rations of the individually-fed pigs, an increase in thyroid weight and a decrease in the body weight to thyroid gland weight ratio occurred. This ratio decreased only 10 per cent in the 2 per cent ROM lot, which is not a significant change; but there was over a 300 per cent reduction in the ratio in the 10 per cent ROM lot when the average values are compared with those obtained on the basal ration.

Photomicrographs of sections of thyroid gland from representative pigs in each of the three lots are presented in Figure 1. At the 2 per cent ROM level there is evidence of some increase in cellular components and limited glandular hypertrophy, while at the 10 per cent level there is a marked increase in cellular components and glandular hypertrophy evident. Study of the histological sections revealed that the thyroid gland from pigs fed ROM appeared to pass through the various pathological stages, namely, epithelial, lymphoid and fibrous tissue, Levitt (14). Differences in stage of thyroid toxicity between animals on the same ration were evident, and differences in histology of various thyroid tissue slices obtained from a single animal were observed. A stain that indicates the state of colloid activity, as suggested by Greep (12), would be useful in obtaining further information in future studies.

TABLE 3.—TOTAL FOOD INTAKE AND GAIN OF RATS FED ROM-CONTAINING DIETS[1]

Ration	ROM	Av. starting weight	Av. final weight	Av. weight gain	Food consumed per rat	Food per gm. gain
	%	gm.	gm.	gm.	gm.	gm.
Starter	0	46.7	329.0	282.3	1948	6.9
	2	46.6	320.0	273.4	2400	8.8
	10	48.2	292.3	244.1	2387	9.8
Mean		47.2	313.8	266.6	2245	8.4
Grower	0	47.4	309.5	262.1	2563	9.8
	2	47.1	335.6	288.5	2622	9.0
	10	47.7	330.7	283.0	2511	9.8
Mean		47.4	325.3	277.9	2565	9.2
Finisher	0	48.0	312.8	264.8	2527	9.5
	2	47.1	313.6	266.5	2043	7.7
	10	47.4	247.1	199.7	1857	9.3
Mean		47.5	291.2	243.7	2142	8.8
0% ROM Mean		47.4	317.1	269.7	2346	8.7
2% ROM Mean		46.9	323.1	276.2	2355	8.5
10% ROM Mean		47.8	290.0	242.2	2252	9.3
Significance level, ROM level in diet				**	n.s.	*

[1]Based on a 148-day period, 3 rats per lot

Rat Gains and Feed Efficiency

The data are presented in Table 3 from a trial with weanling rats fed the nine swine rations for a 148-day period. The over-all results indicate that diets containing 10 per cent ROM were inferior in promoting weight gain and efficiency of food utilization to those containing 0 or 2 per cent ROM. These results from prolonged feeding of ROM to rats are in general agreement with the results of the swine experiments.

Rat I^{131} Studies

At the end of the 148-day period, the 27 rats were utilized for I^{131} studies as outlined under "Materials and Methods"; the results of these studies are presented in Table 4. Both the ROM level and the ration treatment (starter, grower or finisher ration) influenced the ratio of body weight to thyroid weight. There was a tendency, although not significant, for females to exhibit a more hypertrophic gland than males.

To measure thyroid activity and to follow the toxicity of ROM on the thyroid, the T/S ratio was used. The numerator, T, represents the radiological activity of 1 gm. of thyroid tissue and is a value denoting over-all thyroid radioiodine content regardless of form. The denominator, S, is the activity from 1 ml. of blood serum and is the fraction of radioiodine that has been passed through the thyroid gland and is in the organic form or PBI fraction of the serum. The T/S ratio has been in use in studies of this type for some time and was recently used by Taurog *et al.* (20).

An examination of the total thyroid count, T, and T as a percentage of the standard indicates that as the level of ROM rose the per cent T appeared to decline, indicating either a reduced uptake or more rapid turnover rate of iodine. As the level of ROM in the ration rose the T/S ratio

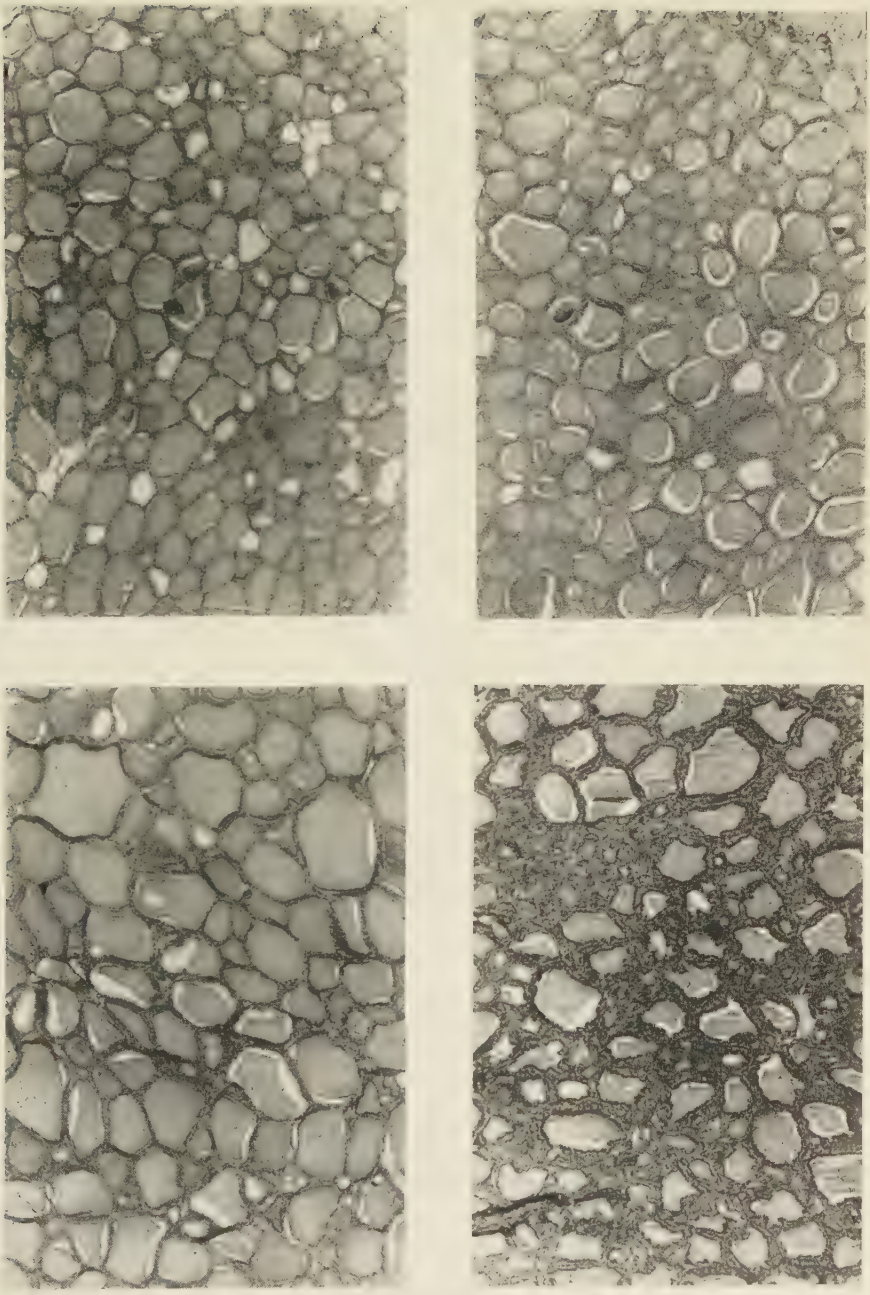

FIGURE 1.—PHOTOMICROGRAPHS OF THYROID SECTIONS

Upper left: 0% ROM, weight of gland 5.2 gm. *Upper right:* 2% ROM, weight of gland 8.7 gm.; showing increase in cellular components. *Lower left:* 10% ROM, weight of gland 16.3 gm; showing marked hypertrophy. *Lower right:* 10% ROM, weight of gland 12.6 gm.; showing large increase in cellular components. (Magnification = 140×).

TABLE 4.—EFFECT OF DIET TYPE AND RAPESEED OIL MEAL LEVEL ON I^{131} TEN HOUR PERIOD UPTAKE AND TURNOVER RATES IN RATS[1]

Ration	ROM	Av. thyroid wt.	Av. thyroid wt. per kg. body wt.	Av. body wt. gm. / thyroid wt. mg.	S = Av. count/min. in 1 ml. serum	T = Total thyroid count/min.	(T) of standard[2]	Av. T/S ratio
	%	mg.	mg.		'000	'000	%	
Starter	0	16.1	52.7	20.8	10.66	451	11.2	43.0
	2	16.6	52.6	19.0	11.23	369	8.5	32.8
	10	14.9	51.3	19.8	12.81	256	5.9	20.0
	Mean	15.9	52.2	19.9	11.57	359	8.5	31.9
Grower	0	19.3	65.3	16.1	13.36	625	13.6	43.9
	2	17.3	54.3	18.4	9.07	516	12.9	55.6
	10	20.3	68.3	14.6	13.33	466	10.7	36.3
	Mean	19.0	62.6	16.4	11.92	536	12.4	45.3
Finisher	0	18.0	56.1	20.5	15.23	627	15.6	41.5
	2	22.7	73.7	13.6	9.53	387	9.6	40.6
	10	20.8	86.4	11.8	12.80	311	7.8	24.6
	Mean	20.5	72.1	15.3	12.52	442	11.0	35.6
ROM level Means	0	17.8	58.0	19.1	13.08	568	13.5	42.8
	2	18.9	60.2	17.0	9.94	424	10.3	43.0
	10	18.7	68.7	15.4	12.98	344	8.1	27.0
ROM level				**				**
Ration treatment				**				**
Sex				n.s.				**
R x T				n.s.				*

[1]Three rats per group, 2 males and 1 female
[2]Standard = 75 microcuries I^{131}. Background = 497 c/m.

TABLE 5.—EFFECT OF CASTRATION ON RAPESEED OIL MEAL TOLERANCE IN RATS[1]

		Females [3]		Males	
		Castrate	Intact	Castrate	Intact
No. of rats		5	4	5	4
Total 3-month gain	gm.	104	64	123	137
Gain per kg. av. wt.	gm.	428	307	408	413
Organ weights per kg.[2]					
Thyroid	mg.	74.1	85.1	77.1	93.6
Pancreas	gm.	2.7	3.0	2.4	2.1
Heart	gm.	3.5	4.0	3.5	3.7
Lungs	gm.	6.7	7.0	6.4	5.2
Liver	gm.	38.5	43.5	41.3	43.3
Kidney	gm.	6.9	7.6	6.7	7.4
Liver					
Dry matter	%	27	27	15	14
N/gm. D.M.	mg.	127	125	211	220
Kidney					
Dry matter	%	27	34	14	13
N/gm. D.M.	mg.	121	122	233	247

[1]All rats were fed swine grower ration containing 10% rapeseed oil meal.
[2]Internal organ weight per kg. is based on per kg. final body weight. All weights are on a fresh weight basis.
[3]The gain per kg. av. wt. was significantly higher, $P < 0.01$ for castrate than for intact females.

declined and ration treatment caused further variation to occur. Sex differences were also evident with females having a lower T/S ratio than males.

The isotope experiments support the histological thyroid studies with swine indicating that an abnormality and biological disturbance occurred in the thyroid glands of animals fed ROM, particularly at a level of 10 per cent of the ration. Sex of the rats, as well as the ration treatment, further influenced the results obtained. The greater susceptibility of females to ROM in the diet supports other work noting sex differences when goitrogens were fed, (11, 15), although some reports, for example (6), have noted the reverse response. It has been stated (1) that factors such as increased bulk in the diet might inhibit reabsorption of organic iodine thus increasing susceptibility to goiter. March and Biely (16) have observed that level of fat in the diet of chicks influenced thyroid weights when thiouracil was fed.

Rat Castration

Data are presented in Table 5 from a study with 46-day old castrate and intact rats of both sexes fed the 10 per cent ROM swine grower ration for a 95-day period. In intact and castrate males an approximate 100 per cent reduction in liver and kidney dry matter, a 70 per cent increase in mg. N/gm. DM in these organs, a reduction in lung weight and an increase in thyroid weight occurred in comparison with females.

Castrate animals had thyroid glands averaging 15 to 20 per cent lighter than intact animals, with a tendency toward a reduction in weight of other organs. These differences in weight were not significant. Ovariectomized females showed a significant increase of 25 per cent in total gain in weight as compared to intact females suggesting that castration reduced the greater sensitivity of females to ROM which had been noted in the earlier experiment.

The over-all results with pigs and rats show that diets containing 10 per cent Argentine type ROM, as used in this experiment, depressed weight gain and had a hypertrophic effect on the thyroid gland as compared to diets containing no ROM. The feeding of a 2 per cent level of ROM resulted in variable effects with no outstanding changes when compared to feeding of the basal diets without ROM.

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RAPESEED OIL MEAL AS A PROTEIN SUPPLEMENT FOR SWINE AND RATS

II. ENERGY AND NITROGEN DIGESTIBILITY AND NITROGEN RETENTION[1,2]

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ABSTRACT

Energy and nitrogen digestibility and nitrogen retention studies are reported for pigs averaging 7, 28 and 62 kg. in weight and for 4- and 6-weeks-old albino rats fed diets containing 0, 2 or 10 per cent expeller extracted Argentine type rapeseed oil meal. The 10 per cent level of the meal depressed apparent digestibility of dry matter, energy and nitrogen with significant effects occurring only in rats. The 2 per cent level of the meal had no significant effect on digestibility. Retention of digestible nitrogen was not altered by the level of rapeseed oil meal in the diet. As indicated by digestibility studies, female rats were more susceptible than males to the presence of rapeseed oil meal in the diet. There were a number of interactions between rapeseed oil meal level and the type of diet fed to rats suggesting that the energy and protein levels of the diet may influence the effect that this meal has on apparent digestibilities of dry matter, energy and nitrogen.

INTRODUCTION

Little, if any, data have been published on the energy and nitrogen digestibility and nitrogen retention of rapeseed oil meal[4] by pigs or rats. Schneider (9) reported digestion coefficients for crude protein in ROM of 86 and 82 per cent for cattle and sheep respectively, while Morrison (8) reported a similar average digestion coefficient of 85 per cent. Total digestible nutrients in ROM were tabulated as 63.3 to 73.5 per cent by Schneider (9) and as 68.1 per cent by Morrison (8). In a review on rapeseed oil meal, Bell (2) stated that "detailed examination of the digestibility data with sheep and cattle reveals consistently lower digestion coefficients for organic matter in rapeseed oil meal as compared to linseed and soybean oil meals. Most of this effect is attributable to the nitrogen-free extract fraction and some to the crude fibre".

This paper reports the results of apparent energy and nitrogen digestibility and nitrogen retention studies with pigs averaging 7, 28 and 62 kg. in weight and with 4- and 6-weeks-old albino rats fed diets containing 0, 2 or 10 per cent Argentine type ROM.

MATERIALS AND METHODS

The animals used in the experiments to be reported were a portion of the same groups of animals for which growth, carcass and thyroid studies are described in a previous paper (4).

Swine Studies

Twelve 21-day-old male pigs were allotted uniformly, in groups of four to three rations, ration 1 containing no ROM, ration 2 containing

[1]Contribution from Department of Animal Science, University of Alberta, Edmonton, Alta.
[2]This study was supported in part by a grant from the National Research Council of Canada.
[3]Adapted from a thesis submitted in partial fulfilment of the requirements for a M.Sc. degree.
[4]For brevity, the abbreviation "ROM" is used subsequently.

2 per cent ROM and ration 3 containing 10 per cent ROM. The expeller extracted Argentine type ROM used in the formulation of rations 2 and 3 contained 37.6 per cent crude protein and 1.5 per cent lysine (3.9 per cent of the protein) and 2 pounds of ROM were added at the expense of 1.6 pounds solvent extracted soybean oil meal and 0.4 pounds wheat. The rations for each period were formulated to contain a constant protein level; the starter rations based on wheat contained 18.4 per cent protein, whereas the grower and finisher rations based on barley, wheat and oats averaged 16.9 and 14.2 per cent protein respectively. Complete details on ration formulation are given in a former paper (4).

Prior to being placed in metabolism cages, the weanling pigs had been on the test rations for several days to become accustomed to the rations. The pigs were allowed a further acclimatization period of 3 to 5 days in the metabolism cages to allow the animals to become accustomed to close confinement. The acclimatization was followed by a 7-day feces and urine collection period. The pigs averaged 7 kg. in weight when the excreta collection was started. Feed and water were supplied *ad libitum*, with the former being fed from a feeder designed to prevent wastage.

A modification of a swine harness described by Kolari *et al.* (5) was used for feces collection. Polythene bags used to collect the feces were removed daily. All fecal material was emptied from the bags and the total feces dried for approximately 12 hours at 105° C. The dried feces were stored in glass bottles and at the end of 7 days the composite fecal samples from each pig were weighed and ground in a Wiley No. 1 Mill to pass a 2-mm. mesh screen. A 100-gm. sample of feces was pulverized by a Weber Pulverizing Mill to pass a 0.024-in. mesh screen. This sample was then stored in a glass bottle until it was analysed for energy and nitrogen. Acidified urine samples, containing cage washings, were weighed and a 250-gm. aliquot from each pig was stored in a ground glass stoppered bottle at 38°F. until the urine was analysed for nitrogen.

The digestibility and retention studies with the grower and finisher feeds were conducted at pig weights of approximately 28 and 62 kg. respectively, using all-metal metabolism crates 19 inches wide, 40 inches long and 28 inches high. Prior to being put in the metabolism crates, the pigs had been fed the ration to be tested for at least 10 days. The animals were on test for a collection period of 5 days preceded by a 2- to 3-day metabolism crate acclimatization period. Lassiter *et al.* (6) have noted that for digestibility and retention studies with pigs a 7-day collection period offers little advantage over a 3-day period when either is preceded by a ration acclimatization period of 10 days.

With the larger quantities of urine and fecal material from the growing and finishing hogs as compared to the weanling pigs modifications were necessary in collection methods. The animals were on screened floors allowing the fecal samples to drop on a sloped tray below. The feces were collected daily and dried, weighed and made into composite samples as described previously. Urine was collected in 10-litre styrene plastic buckets and acidified using 75 ml. of 50 per cent H_2SO_4 per bucket. Following daily weighing of the urine, an aliquot of 1/10 of the total

weight was taken and stored in a glass stoppered bottle at 38°F. The combined aliquot at the end of the 5-day collection period was clarified by gravity sedimentation prior to nitrogen analysis.

Rat Studies

Albino rats of the Sprague Dawley strain averaging 46 to 48 gm. in weight were weaned at 21 days of age and allotted to nine groups of 3 rats each. The diets used were the same as were fed to the pigs, i.e. starter, grower and finisher rations containing 0, 2 or 10 per cent ROM in each case, with each rat receiving a specific diet for the entire experimental period.

After allotment the weanling rats were placed in Type LC-75/A[1] cages for a 7-day ration and cage acclimatization period. Energy digestibility and nitrogen retention trials were then carried out for 7 days using Type LC-176[1] metabolism cages with Type LC-278[1] Joy food cups to allow *ad libitum* food consumption. After a 7-day interval, the rats were again placed in the metabolism cages for 7 days, thus giving data for 4-to-5 and 6-to 7-weeks-old rats in each case. Details of the methods used in the trials with rats are described by Sibbald *et al.* (10). When data were corrected to an average body weight basis, the average of the initial and final weights during the test period were used.

Nitrogen analyses of feeds, feces and urine from both the swine and rat studies were conducted by the Kjeldahl-Gunning method using boric acid to retain the ammonia. Caloric values for fecal and feed samples were obtained with a Parr Oxygen Bomb Calorimeter. Some of the fecal samples were left unpelleted so that they could be completely combusted in the bomb. The calculations of apparent digestible energy[2], apparent digestible nitrogen and retention of digestible nitrogen were as outlined by Sibbald *et al.* (10).

Methods of statistical analyses were as outlined in a previous paper (4).

RESULTS AND DISCUSSION

Swine Studies

Table 1 presents the data from the energy and nitrogen digestibility and nitrogen retention trials with swine. All data are expressed in metric units or percentages to simplify comparisons with the rat data.

In each of the three experimental periods there was no significant difference in weight gain of the pigs fed the different levels of ROM. When the pigs were placed in the metabolism cages, there was evidence of a marked irritability and sensitivity of the pigs fed 10 per cent ROM as compared to those fed 0 or 2 per cent ROM diets. A similar nervous condition is observed in hyperthyroid humans (7).

In the starter period, there was a 30 per cent decline in feed consumption in pigs fed 10 per cent ROM as compared with that of those fed 0 or 2 per cent ROM rations. This reduction in feed consumption was not

[1]Geo. H. Wahmann Mfg. Co., Baltimore, Maryland.

[2]The following abbreviations will be used subsequently:
ADE = apparent digestible energy; ADN = apparent digestible nitrogen; DM = dry matter; ABW = average body weight during the collection period; and OD = oven dry.

TABLE 1.—RATION ANALYSIS AND DIGESTIBILITY AND RETENTION DATA RELATING TO THE PIG[1]

Ration	Starter			Grower			Finisher		
ROM level %	0	2	10	0	2	10	0	2	10
No. pigs[2]	4	4	4	4	4	4	2	3	4
Length of collection period..days	7	7	7	5	5	5	5	5	5
Av. weight of pigs on test....kg.	7.16	7.53	6.35	28.7	28.1	26.2	60.9	65.3	61.1
Feed analysis:									
Gross nitrogen....mg./100 gm.	2977	2946	2904	2723	2739	2737	2458	2465	2376
Gross energy....Cal./100 gm.	397	396	398	404	410	413	407	408	404
Weight gain:									
Per pig.....kg.	1.61	1.67	1.12	4.20	4.52	4.78	5.91	5.90	4.08
Per kg. ABW..... gm.	211	222	176	146	161	182	97	90	67
Feed consumption (OD basis).kg.	2.18	2.16	1.44	8.70	7.52	7.63	15.54	14.95	17.25
DM digested.....%	88	88	85	81	78	72	81	82	83
ADN.....%	80	85	79	78	77	70	82	85	85
ADN retained.....%	41	39	42	58	56	44	47	44	61
ADE.....%	86	87	84	80	77	72	81	82	82
ADE/kg. ABW.....Cal.	1053	1070	824	933	921	959	831	828	1024

[1]The only statistically significant difference in the data was in feed consumption in the finishing period where the 10% ROM pigs ate more than the 0 or 2% ROM individuals. $P < 0.01$.

[2]Numbers of animals are reduced on the 0 and 2% ROM finisher rations because there was a restriction in feed intake, for the animals removed, during the collection period. The faulty equipment design which caused this restriction was subsequently corrected.

uniform and was not significant. The only statistically significant difference in feed consumption was in the finishing period where the pigs receiving rations with 10 per cent ROM ate more than those receiving 0 or 2 per cent ROM rations. These data agree with results of feeding trials with this same meal (4), and indicate that there was no apparent palatability problem associated with the use of ROM in this experiment. Lack of palatability has been reported by other workers, for example Bell (2), as contributing to the low supplemental value of ROM.

ADE intake reported on the basis of ABW was essentially constant at each growth stage regardless of the level of ROM in the rations. Two figures appear somewhat at variance; the ADE intake tends to be low in the starter period and high in the finisher period for the 10 per cent ROM pigs.

The percentages of dry matter, nitrogen and energy digested were similar in each period for pigs fed rations containing 0 or 2 per cent ROM. There was a definite, but not significant, trend toward reduced digestibilities of these three factors in pigs fed the 10 per cent level of ROM in the starter and grower periods but this trend was not evident in the finisher period.

The ADN retention was variable with no trend being established in these trials.

Barber *et al.* (1) and Berg and Bowland (3) have stated that restricted feeding in swine resulted in improved feed utilization as compared with appetite-fed hogs. The individually-fed animals used for the studies reported ate less than group-fed counterparts (4); this raises a question as to whether this restriction in feed intake may influence digestibility and retention studies, particularly when goitrogenic products are fed.

Rat Studies

The data from the rat trials are reported in Table 2 and these observations support the results and trends obtained from the swine digestibility and retention trials.

With 4-weeks-old rats total weight gain per rat and weight gain/kg. ABW were not influenced by the ROM level, ration treatment (starter, grower or finisher ration) or sex. With 6-weeks-old rats total weight gain was affected by these factors as well as by an R x T interaction. When gain was corrected to an ABW basis the influence of ROM level and sex remained. After a period of 3 to 4 weeks on a particular diet it appeared that ROM-containing diets reduced the rate of gain as compared to that obtained on the basal diets. Female rats gained more slowly than males during this same period.

Food consumption was not significantly altered by the level of ROM in the diet nor by the ration treatment. In the 6-weeks-old rats there was an interaction R x T associated with food consumption, but with the complex relationships involved no comprehensive explanation of this interaction can be offered. ADE intake/kg. ABW was not influenced by any of the dietary factors which is further evidence that rats tend to consume food in relation to the available energy level of the diet. This relationship has been postulated by Sibbald *et al.* (10). During the second

TABLE 2.—DIGESTIBILITY AND RETENTION DATA RELATING TO THE RAT

Ration	Starter			Grower			Finisher			ROM level	Ration treatment	Sex	RxT
ROM level %	0	2	10	0	2	10	0	2	10				
No. rats	3	3	3	3	3	3	3	3	3				
1st trial													
Av. wt.....gm.	81.0	80.6	75.7	77.3	75.3	75.1	75.7	75.7	63.1				
Weight gain													
Per rat.....gm.	31.4	29.6	30.2	36.1	27.5	28.9	33.5	28.7	15.6	n.s.	n.s.	n.s.	n.s.
Per kg. ABW....gm.	98.5	95.2	101.1	114.1	94.4	99.1	108.4	96.7	58.6	n.s.	n.s.	n.s.	n.s.
Food cons. (OD)..gm.	83.2	79.7	82.4	96.3	79.7	84.0	91.6	84.0	60.7	n.s.	n.s.	n.s.	n.s.
DM digest.....%	86.1	86.7	84.2	78.7	78.7	77.7	77.9	78.1	74.8	**	**	**	n.s.
ADN.....%	82.2	83.5	79.1	78.9	76.9	75.9	80.4	82.0	72.2	**	**	n.s.	*
ADN retained.....%	56.2	50.3	52.1	59.8	53.7	54.5	60.4	56.4	38.3	n.s.	*	n.s.	n.s.
ADE.....%	85.3	86.3	83.8	79.1	79.5	78.4	78.5	78.7	74.7	**	**	**	**
ADE/kg. ABW...Cal.	314	311	301	340	309	330	309	326	274	n.s.	n.s.	n.s.	n.s.
2nd trial													
Av. wt.....gm.	139.6	142.2	133.9	134.7	133.1	129.2	130.1	127.6	102.5				
Weight gain													
Per rat.....gm.	37.2	24.4	27.2	26.7	14.6	25.3	31.4	40.3	16.1	*	*	*	**
Per kg. ABW...gm.	69.8	47.1	54.9	53.4	30.6	46.5	64.6	79.7	52.0	*	n.s.	*	n.s.
Food cons. (OD)..gm.	99.7	78.6	89.9	101.6	83.8	91.9	99.6	116.8	79.4	n.s.	n.s.	*	**
DM digest.....%	86.4	84.6	83.3	78.7	78.3	76.1	74.8	76.7	69.7	**	**	**	**
ADN.....%	84.1	83.3	80.2	81.4	78.2	75.2	75.1	78.3	69.4	**	**	**	**
ADN retained.....%	38.6	27.6	30.9	41.6	36.6	24.8	48.7	47.1	33.8	n.s.	n.s.	*	n.s.
ADE.....%	85.8	83.7	82.4	78.9	78.4	76.9	75.3	76.8	70.4	**	**	**	**
ADE/kg. ABW...Cal.	231	213	215	236	208	222	227	267	220	n.s.	n.s.	n.s.	n.s.
Summary													
DM digest.....%	86.3	85.6	83.8	78.7	78.3	76.9	76.4	77.4	72.4				
ADN.....%	83.2	83.4	79.6	80.2	77.6	75.6	77.8	80.2	70.8				
ADN retained.....%	47.4	39.0	41.5	50.7	45.2	39.7	54.6	51.8	36.1				
ADE.....%	85.6	85.0	83.1	79.0	79.0	77.6	76.9	77.7	72.6				

* = Significant at $P < 0.05$
** = Significant at $P < 0.01$
n.s. = Non-significant

trial, food consumption was lower for females than males but this was because of the smaller size of the female rats. On the basis of ADE intake/kg. ABW, sex had no influence on ADE consumption.

The digestibilities of DM, energy and nitrogen were significantly lowered by the addition of ROM to the diet in both series of trials. The ration treatment also affected DM digestibility, ADN and ADE. As the diets varied from 18.4 to 14.2 per cent protein and to a lesser extent in available energy, the results suggest that protein and energy levels in a diet may influence the effect which ROM has on dry matter, energy and nitrogen digestibilities. The possibility exists that variation in vitamin levels in the diets had an influence on ROM toxicity.

Several interactions between ROM levels and ration treatment occurred. These interactions were the result of reversals in digestibility coefficients between 0 and 2 per cent ROM diets of different types, and in the degree of spread in results between 10 per cent ROM diets and those containing lower levels of the meal.

Percentage digestibilities of DM, energy and nitrogen were lower for females than males, particularly at the 10 per cent level of ROM. The results suggest that females are more susceptible than males to ROM in the diet. Growth and thyroid studies as reported previously (4) support this evidence of a sex effect on response to ROM toxicity.

The retention of ADN was variable but was influenced to some extent by ration treatment and by sex. ROM levels in the diet did not influence nitrogen retention which is in agreement with the results obtained from the swine experiments.

The digestibility data indicate, that for the rat, ROM was not a satisfactory replacement for soybean oil meal. The observations were less definite for pigs but 10 per cent ROM in the diet tended to depress apparent digestibilities in comparison to 0 or 2 per cent ROM in the diet. These experiments did not indicate whether the lowered percentage digestibilities of DM, ADE and ADN were associated with a nutritional imbalance such as low lysine or with the presence of some toxic factor in the meal. Percentage ADN retained was not influenced by the ROM level in the diet and this is strongly suggestive that during the period covered by these trials ROM did not interfere to a marked degree with body metabolic processes associated with nitrogen retention even though thyroid gland changes as reported in a previous paper (4) were evident.

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INFLUENCE OF STRAIN AND SEX ON THE RELATIONSHIP OF PROTEIN TO ENERGY IN THE RATIONS OF GROWING AND FINISHING BACON PIGS

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ABSTRACT

Rations varying in energy (65 to 79 per cent TDN or 69 to 88 per cent apparent digestible energy) and protein (13 to 21 per cent) were studied in two experiments with 120 pigs of four strains. Rate of liveweight gain tended to be fastest in pigs fed high energy-high protein rations throughout. Males gained more rapidly than females, with strain differences being evident. Strain × sex interactions in rate of gain were present in both the growing and finishing period, with a ration × strain interaction present in the growing period. There was an indication that in the growing period pigs on high energy, particularly high energy-high protein rations ate more than pigs fed low energy rations. In the finishing period low energy rations were consumed at a higher rate than high energy rations with protein level having no influence on feed intake. In the growing period to 110 pounds, high protein rations resulted in improved feed efficiency as compared to medium protein rations, while in the finishing period to market weight high energy rations were more efficient than low energy rations. There was evidence that high protein alone or in combination with high energy rations also improved efficiency of feed utilization in the finishing period. Female pigs required less feed per pound gain than male pigs in the finishing period. High energy rations resulted in increased dressing percentage and generally inferior carcasses. There was an indication that high protein rations resulted in leaner carcasses. Carcass length was not influenced by ration. Carcasses from female pigs excelled those from male pigs in all factors measured except carcass length. Strain differences in carcass characteristics existed but no appreciable strain × ration interactions were noted.

INTRODUCTION

An optimum ratio between dietary energy and the requirement for nitrogen has been demonstrated on numerous occasions, as for example Sibbald *et al.* (13), with the weanling rat and Hill and Dansky (7), with the chick. In pigs little information is available on whether such an optimum ratio exists, or what this ratio is if it does exist. It is also necessary to define the criterion of measurement in hogs, as rate of gain and efficiency of feed utilization may have different protein-energy optima to that required for high carcass quality. A number of workers, for example, Hironaka and Bowland (8), and Jensen *et al.* (9), have noted that protein level in the ration affected rate of gain in pigs fed a fixed energy level. In a recent report, Abernathy *et al.* (1) studied protein and energy interrelationships in diets for growing swine and found that increased caloric density resulted in a highly significant linear increase in gains and efficiency of feed utilization. Eighteen per cent protein improved gains over fourteen per cent protein for the first 42-day period on trial. Ashton *et al.* (3) observed that feeding pigs protein levels over the range from 10 to 20 per cent of the ration resulted in carcasses with a significantly greater proportion of lean as the level of protein increased.

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Carcass characteristics in Yorkshire hogs have been shown to vary appreciably between sexes [Fredeen (6)], and it is probable that optimum protein to energy ratios may differ between sexes, at least in relation to ultimate carcass quality. Different strains of pigs responded in a similar relative manner to frequency of feeding [Bowland and Berg (5)], but Lucas and Calder (10) reported certain differences in relative response of breeds of varying type to different planes of feeding. Little information has been published on response of strains or breeds to levels of nitrogen and energy in the ration.

This report is a summary of two feeding trials with four strains of growing and finishing pigs of both sexes fed natural rations varying in protein level as well as total digestible nutrients. Data are reported on the influence of ration, strain and sex on rate of gain, feed consumption, efficiency of feed utilization and carcass characteristics.

MATERIALS AND METHODS

In Experiments 1A, conducted during the summer of 1956, and 1B, conducted during the winter of 1956-57, a total of 56 weanling pigs, 24 in the first replicate and 32 in the second replicate, were allotted to 8 lots in each experiment. Sexes were equalized in the over-all experiment with 2 Yorkshire (Y) and 1 Lacombe × Yorkshire (LY) per lot in Replicate 1, and 2 of each strain per lot in Replicate 2. The rations fed during the growing and finishing periods are outlined in Table 1. The formulation and composition of all rations are listed in Table 3.

Table 1.—Rations fed in energy-protein Experiments 1A and B

Lot No.	Growing (start to 110 lb.)	Finishing (110 lb. to market)
1	High energy-high protein	High energy-high protein
2	High energy-high protein	High energy-low protein
3	Low energy-high protein	Low energy-high protein
4	Low energy-high protein	Low energy-low protein
5	High energy-medium protein	High energy-medium protein
6	High energy-medium protein	High energy-low protein
7	Low energy-medium protein	Low energy-medium protein
8	Low energy-medium protein	Low energy-low protein

Table 2.—Rations fed in energy-protein Experiment 2

Lot No.	Growing (start to 110 lb.)	Finishing (110 lb. to market)
1	High energy-high protein	High energy-high protein
2	High energy-high protein	High energy-low protein
3	Low energy-high protein	Low energy-high protein
4	Low energy-high protein	Low energy-low protein

TABLE 3.—FORMULATION AND COMPOSITION OF RATIONS IN ENERGY-PROTEIN STUDIES

Rations	HE-HP	HE-MP	HE-LP	LE-HP	LE-MP	LE-LP
Ingredients						
Wheat	70.0	82.0	61.0	—	—	—
Corn*	10.0	10.0	35.0	—	—	—
Oats	—	—	—	63.0	74.5	83.5
Wheat bran	—	—	—	10.0	10.0	10.0
Protein supplement†	18.9	6.9	2.9	25.9	14.4	5.4
Iodized salt	0.5	0.5	0.5	0.5	0.5	0.5
Ground limestone	0.5	0.5	0.5	0.5	0.5	0.5
Zinc sulphate	0.05	0.05	0.05	0.05	0.05	0.05
Antibiotic supplement‡	0.05	0.05	0.05	0.05	0.05	0.05
Experiments 1A and B						
Av. crude protein %	20.9	16.4	14.5	22.3	17.7	15.0
Crude fibre %	4.1	3.5	3.0	9.8	10.1	10.0
Total digestible nutrients (calculated) %	78.6	79.1	79.7	65.9	65.0	64.3
Apparent digestible energy %	86	88	88	68	67	71
Apparent digestible nitrogen %	83	86	86	78	78	74
Experiment 2						
Crude protein %	20.4	–	12.6	20.9	–	13.4

*In Experiment 1A, wheat replaced all of the corn in the HE-HP and HE-MP rations and 15% of the corn in the HE-LP ration.

†The protein supplement was formulated as follows:

	Experiments 1A and B	Experiment 2
Soybean oil meal	75.0	75.0
Fish meal	10.0	10.0
Feeding tankage	15.0	—
Meat meal	—	15.0
	100 lb.	100 lb.

The supplement contained 48.7% protein in Experiments 1A and B and 46.9% protein in Experiment 2. Dry vitamin A and Dry vitamin D_3 were supplied at levels of 1 million and 200,000 I.U. respectively per ton of total ration.

‡The antibiotic supplement (TM-10) contained 10 gm. of terramycin per lb. Supplied through the courtesy of Pfizer Canada, Montreal, Que.

In Experiment 2, conducted during the summer of 1957, 64 weanling pigs were allotted in a 2^4 factorial design to 16 lots, 8 each of Yorkshire × Lacombe-Yorkshire (Y(LY)) backcross and Tamworth x Lacombe-Yorkshire (T(LY)) 3-way crossbred pigs. The 8 lots of each strain were divided into 4 lots each of males and females and each sex fed the rations outlined in Table 2.

As listed in Table 3 the HE* rations were based on wheat and corn, the corn being necessary to lower protein to a level in the HE-LP group comparable with that in the LE-LP lot. The LE rations were based on oats and wheat bran.

In Experiment 1 the rations were formulated to give calculated TDN levels [Schneider (12)], approximately 5 per cent above and 10 per cent

*The following abbreviations are used: HE = high energy; LE = low energy; HP = high protein; MP = medium protein, and LP = low protein.

TABLE 4.– SUMMARY OF AVERAGE DAILY GAIN AND EFFICIENCY OF FEED UTILIZATION—EXPERIMENTS 1A AND B

	No.	Weight on trial	Growing Period			Finishing Period			Total Period		
			Av. daily gain	Av. daily feed	Feed/lb. gain	Av. daily gain	Av. daily feed	Feed/lb. gain	Av. daily gain	Av. daily feed	Feed/lb. gain
		lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Expt. 1A and 1B	56	42.2	1.39	4.6	332	1.59	6.8	429	1.49	5.8	389
Ration		n.s.	*	*	n.s.	n.s.	n.s.	*	n.s.	n.s.	*
HE–HP, HE–HP	7	41.1	1.58	4.9	307	1.67	6.4	383	1.63	5.7	348
HE–HP, HE–LP	7	42.9	1.58 (1.58)	5.0 (5.0)	318 (313)	1.62	6.7	412	1.60	6.0	372
LE–HP, LE–HP	7	42.9	1.38	4.2	307	1.57	6.9	442	1.48	5.7	382
LE–HP, LE–LP	7	42.3	1.33 (1.35)	4.5 (4.3)	340 (324)	1.55	7.1	459	1.45	5.9	408
HE–MP, HE–MP	7	41.4	1.32	4.5	343	1.76	7.0	398	1.53	5.7	373
HE–MP, HE–LP	7	42.6	1.31 (1.32)	4.5 (4.5)	341 (342)	1.47	5.9	402	1.39	5.2	375
LE–MP, LE–MP	7	42.6	1.29	4.6	355	1.50	7.0	469	1.40	5.9	422
LE–MP, LE–LP	7	42.0	1.33 (1.31)	4.6 (4.6)	343 (349)	1.45	6.7	464	1.39	5.6	401
Strain		n.s.	**			n.s.			**		
Yorkshire	32	43.4	1.31	–	–	1.54	–	–	1.44	–	–
Lacombe-York.	24	40.6	1.48	–	–	1.65	–	–	1.57	–	–
Sex		n.s.	n.s.			**			**		
M	28	41.6	1.42	–	–	1.71	–	–	1.57	–	–
F	28	42.8	1.35	–	–	1.46	–	–	1.41	–	–
Replicate		**	n.s.	**	**	n.s.	n.s.	n.s.	n.s.	**	**
A	24	53.1	1.35	4.9	369	1.60	6.9	436	1.49	6.1	409
B	32	34.1	1.42	4.4	311	1.58	6.6	425	1.50	5.4	369

*Significant at $P < 0.05$
**Significant at $P < 0.01$
n.s. Non-significant

TABLE 5.—SUMMARY OF AVERAGE DAILY GAIN AND EFFICIENCY OF FEED UTILIZATION—EXPERIMENT 2

	No.	Weight on trial	Growing Period			Finishing Period			Total Period		
			Av. daily gain	Av. daily feed	Feed/lb. gain	Av. daily gain	Av. daily feed	Feed/lb. gain	Av. daily gain	Av. daily feed	Feed/lb. gain
		lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Expt. 2	64	58.3	1.71	5.1	300	1.73	7.1	412	1.72	6.3	365
Ration			n.s.	*	n.s.	*	n.s.	**	n.s.	n.s.	n.s.
HE–HP, HE–HP	16	59.2	1.76	5.2	296	1.83	7.1	389	1.81	6.3	350
HE–HP, HE–LP	16	59.2	1.72 (1.74)	5.3 (5.3)	308 (302)	1.67	6.8	410	1.70	6.2	370
LE–HP, LE–HP	16	58.3	1.72	4.9	287	1.68	7.1	422	1.70	6.2	365
LE–HP, LE–LP	16	59.1	1.64 (1.68)	5.0 (4.9)	307 (297)	1.73	7.4	425	1.70	6.4	376
Strain			*	**	**	n.s.	n.s.	**	n.s.	n.s.	**
T(LY)	32	58.7	1.66	5.4	324	1.72	7.2	421	1.70	6.5	382
Y(LY)	32	57.8	1.76	4.8	276	1.74	7.0	403	1.75	6.1	349
Sex			**	**	n.s.	*	*	**	**	*	*
M	32	59.0	1.85	5.4	294	1.78	7.5	425	1.81	6.7	371
F	32	57.5	1.58	4.8	304	1.68	6.7	399	1.64	5.8	359
Ration x Strain			**	*				*			
Strain x Sex			**			**					

* Significant at $P < 0.05$
** Significant at $P < 0.01$
n.s. Non-significant

below N.R.C. recommended requirements (11). The medium protein levels met, or were slightly above, the suggested N. R. C. requirements for 50-lb. pigs, while the low protein levels were slightly above requirements for finishing hogs. The high protein levels were above the N. R. C. recommended levels for all classes of hogs. Apparent digestible energy and nitrogen were obtained on these rations using weanling albino rats as the test animal. These percentage digestibilities are listed in Table 3. The digestibility figures indicate a slightly wider range in available energy in the rations than is shown by calculated TDN figures. There is a 5 to 10 per cent reduction in percentage digestible nitrogen in the low energy diets even though the total nitrogen is as high as in the high energy diets.

To allow a more complete comparison of sex and strain differences, the design of Experiment 2 was simplified to include only a high and low level of protein with similar energy levels to those used in Experiment 1. The strains used in this experiment were known from previous observations to differ considerably in carcass characteristics.

All rations were self-fed with water available *ad libitum* from automatic waterers. The pigs were housed on concrete floors in a heated piggery.

Carcass measurements and scores were obtained under Canadian Advanced Registry for Swine (2) standards, while Government grades were obtained on all carcasses.

RESULTS AND DISCUSSION

The means of the data along with results from analysis of variance relating to rate of grain, feed consumption and efficiency of feed utilization are in Table 4 for Experiments 1A and B, and in Table 5 for Experiment 2. The carcass data means from Experiment 1 are listed in Table 6 and from Experiment 2 in Table 7. The individual effects of energy, protein and interaction were separated in the analysis of variance and are shown separately in Table 8. Analysis of covariance, in an attempt to remove any effect of hot carcass weight on carcass characteristics, was conducted in both experiments. The adjusted means are reported where a significant reduction in error sums of squares was achieved through covariance analysis. In those cases the test of significance was made for differences between adjusted means. The data from Tables 4 and 5 and from 6 and 7 will be discussed simultaneously.

In Replicate A of Experiment 1 the pigs were significantly heavier when placed on trial than in Replicate B; however, weights were equalized for ration, sex and strain. In Experiment 2, all lots were adjusted to a similar starting weight of approximately 58 pounds.

Rate of Gain

In the period up to 110-lb. average weight, in Experiment 1 the pigs on HE-HP rations grew more rapidly than pigs on any other ration. In Experiment 2, protein levels did not vary in the growing period. Therefore, only the effects of energy levels were studied and the small difference in gain in favour of pigs fed high energy rations was not significant. Strain differences in rate of gain in the growing period existed in both experiments. Males grew faster than females but this was significant only in the second

TABLE 6.—SUMMARY OF CARCASS MEASUREMENTS AND GRADES—EXPERIMENTS 1A AND B

	No.	Hot carcass wt.	Dressing	Carcass length	Av. backfat	Ham	Loin area	Belly score	Total A.R. score	Carcass Grades			
										A	B_1	C	B_2
		lb.	%	in.	in.	%	sq. in.	(20)	%	%	%	%	%
Expt. 1A and 1B	54	154.4	78.9	30.0	1.51	23.6	3.64	12	61	46	44	7	3
Ration		n.s.	*	n.s.	*	n.s.	n.s.	**	*				
HE–HP, HE–HP	7	159.3	79.8	30.3	1.56	23.4	3.77	12	63	43	43	14	0
HE–HP, HE–LP	7	157.4	79.5	30.1	1.68	23.0	3.29	7	44	14	57	29	0
LE-HP, LE–HP	7	151.9	77.8	30.0	1.42	23.6	3.88	15	67	57	43	0	0
LE–HP, LE–LP	7	150.8	76.6	29.9	1.43	23.6	3.80	16	72	86	14	0	0
HE–MP, HE–MP	7	156.1	79.3	30.1	1.59	23.6	3.46	9	54	29	71	0	0
HE–MP, HE–LP	7	156.6	80.4	30.0	1.61	23.3	3.48	6	50	29	57	14	0
LE–MP, LE–MP	7	150.4	76.7	29.8	1.40	23.9	3.79	15	66	43	43	0	14
LE–MP, LE–LP	5	150.8	76.7	30.0	1.35	24.0	3.61	18	76	80	20	0	0
Strain		n.s.	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.				
Yorkshire	30	155.1	79.3	29.8	1.52	23.7	3.72	12	59	40	53	7	0
Lacombe-York.	24	153.6	78.3	30.2	1.50	23.4	3.53	12	63	54	33	9	4
Sex		n.s.	*	n.s.	**	**	**	**	**				
M	28	154.9	78.3	29.9	1.58	23.3	3.39	10	53	36	50	14	0
F	26	153.9	79.5	30.1	1.44	23.8	3.90	14	69	58	38	0	4
Replicate		**	**	n.s.	n.s.	*	n.s.	**	n.s.				
A	23	157.9	79.9	30.0	1.54	23.7	3.65	10	57	39	52	9	0
B	31	151.8	78.1	30.0	1.49	23.4	3.63	13	64	52	39	6	3

* Significant at $P < 0.05$
** Significant at $P < 0.01$
n.s. Non-significant

TABLE 7.—SUMMARY OF CARCASS MEASUREMENTS AND GRADES—EXPERIMENT 2

	No.	Hot carcass wt.	Dressing	Carcass length	Adjusted av. backfat	Ham	Loin area	Adjusted belly score	Adjusted total A.R. score	Carcass Grades		
										A	B_1	C
		lb.	%	in.	in.	%	sq. in.	(20)	%	%	%	%
Expt. 2	64	153.2	78.4	31.2	1.42	23.5	3.67	15	75	67	31	2
Ration		*	**	n.s.	n.s.	**	n.s.	**	**			
HE–HP, HE–HP	16	154.2	79.1	31.3	1.42	23.5	3.65	15	75	63	37	0
HE–HP, HE–LP	16	156.1	79.5	31.7	1.48	23.0	3.47	12	69	56	38	6
LE–HP, LE–HP	16	150.7	77.3	31.2	1.40	23.7	3.75	17	78	69	31	0
LE–HP, LE–LP	16	151.7	78.0	31.1	1.40	23.8	3.78	16	80	81	19	0
Strain		n.s.	*	**	**	**	n.s.	**	**			
T(LY)	32	154.0	78.9	30.8	1.54	23.0	3.59	13	67	41	56	3
Y(LY)	32	152.3	78.1	31.7	1.31	24.0	3.73	16	84	94	6	0
Sex		n.s.	n.s.	n.s.	**	**	**	**	**			
M	32	153.9	78.5	31.2	1.47	23.2	3.36	13	70	66	34	0
F	32	152.4	78.4	31.4	1.38	23.8	3.96	17	81	69	28	3

* Significant at $P < 0.05$
** Significant at $P < 0.01$
n.s. Non significant

experiment. A ration × strain as well as a strain × sex interaction was observed in Experiment 2. Table 9 gives the average daily gains from which these interactions are calculated. These results suggest that in the growing period up to 110 lb. of weight not only absolute differences may exist between strains and sexes but that the magnitude of such differences may vary with a particular protein and energy level.

In the finishing period in Experiment 2, pigs fed a HE-HP ration gained more rapidly than those fed other rations, while in Experiment 1 pigs fed HE rations gained faster than pigs fed low energy rations with no appreciable effect of protein level either alone or in combination with any particular energy level. Males gained more rapidly than females in the finishing period with no strain differences being evident. A strain × sex interaction occurred in rate of gain in the finishing period. The strain × sex interactions in rate of gain in the growing and finishing periods may indicate different physiological growth curves for the sexes of the two strains studied.

The average daily gains for the total period are a summary of the growing and finishing periods and therefore show the over-all effects of these two periods. Although the results are not clear-cut, pigs fed HE-HP rations throughout tended to gain faster than pigs fed other rations. These findings are compatible with the hypothesis that HE and HP rations alone and in combination favourably influence rate of liveweight gain in swine. Males gained more rapidly than females in both experiments. LY pigs outgained Y pigs in Experiment 1. There was no difference in rate of liveweight gain between strains in Experiment 2 in the total period although T(LY) gained more rapidly than Y(LY) in the growing period.

Feed Consumption

In the growing period in Experiment 2, where only energy levels differed, pigs fed HE rations consumed more feed per day than pigs fed LE rations, while in Experiment 1, where protein and energy levels differed, the pigs fed HE-HP rations consumed more feed than other groups. In the finishing period essentially the reverse situation occurred with pigs fed LE rations consuming more feed per day than those fed HE rations although this was significant only in Experiment 1. There was no apparent influence of protein level in the ration, alone or in combination with energy level, on the amount of daily feed consumed in the finishing period. The inverse relationship of available energy content of the diet with feed consumption was only indicated in the finishing period in these trials and does not appear to be as well defined as in other species such as rats (13) and chicks (7). Further evidence for this statement is provided by a co-operative Canadian experiment (4), where there were no consistent differences in feed consumption between pigs finished on barley and oat rations.

In Experiment 1, feed consumption data for individual sexes could not be separated but in Experiment 2 male pigs ate more than females throughout. In Experiment 2, the T(LY) strain ate more feed per day than the Y(LY) strain in the growing period but not in the finishing period.

Efficiency of Feed Utilization

Pigs fed HP rations were more efficient in feed utilization than those fed MP rations in the growing period. While energy level had no effect

TABLE 8.— MEAN SQUARES FOR AVERAGE DAILY GAIN, EFFICIENCY OF FEED UTILIZATION AND CARCASS MEASUREMENTS AND SCORES, EXPERIMENTS 1 AND 2

	d.f.[1]	Growing period			Finishing period			Total period			Carcass measurements and scores							
		Av. daily gain	Av. daily feed	Feed/lb. gain	Av. daily gain	Av. daily feed	Feed/lb. gain	Av. daily gain	Av. daily feed	Feed/lb. gain	Hot weight	Dressing %	Length	Adj.[2] backfat	Ham %	Loin area	Adj.[2] belly score	Adj.[2] A.R. score
Expt. 1A and B																		
Ration	7	0.23*	0.29*	856	0.09	0.37	2123*	0.06	0.15	1095*	81.8	8.91*	0.15	0.09*	0.70	0.29	131.7**	796*
Energy	1	0.17**	0.25*	16	0.28*	0.96*	15006**	0.21**	0.09	5476**	545.2**	49.27**	0.52	0.55**	2.76**	1.05*	770.6**	3987**
Protein	2	0.32**	0.11	2,550*	0.03	0.25	621	0.03	0.05	962	19.0	0.55	0.16	0.01	0.53	0.36	11.9	155
E x P	2	0.19**	0.51**	4	0.10	0.07	178	0.01	0.03	117	3.5	2.30	0.06	0.01	0.17	0.05	58.9*	560
Strain	1	0.43**			0.15			0.22**			40.1	17.61*	1.93	0.01	1.38	0.47	7.2	275
Sex	1	0.06			0.91**			0.34**			20.7	15.22*	0.52	0.25**	4.40**	3.48**	284.5**	3205**
Replicate	1	0.05	1.59**	13,806**	0.01	0.31	506	0.00	1.86**	6162**	521.1**	48.49**	0.09	0.03	1.44*	0.01	123.0**	517
Rat. x Str.	7	0.05			0.07			0.01			14.3	0.45	0.21	0.02	0.31	0.24	27.8	207
Rat. x Sex	7	0.02			0.02			0.00			16.7	0.83	0.32	0.03	0.45	0.05	22.9	209
Rat. x Rep.	7	0.04			0.04			0.02			40.1	0.49	0.38	0.02	0.16	0.35	5.3	123
Str. x Sex	1	0.03			0.04			0.06			12.9	0.61	0.31	0.03	0.45	0.04	14.9	430
Str. x Rep.	1	0.03			0.04			0.01			42.1	6.69	0.59	0.00	2.26*	0.82	5.8	107
Sex x Rep.	1	0.06			0.01			0.00			17.7	0.71	1.60	0.00	0.05	0.01	27.2	801
Error	21	0.02	0.04	500	0.05	0.12	597	0.03	0.13	234	38.2	2.59	0.53	0.03	0.32	0.14	12.8	230
Expt. 2																		
Ration	3	0.06	0.40*	110	0.10*	0.18	1031**	0.05	0.03	489	94.7*	16.15**	0.50	0.02	1.81**	0.23	64.4**	292*
Energy	1				0.02	0.24	2167**	0.01	0.00	440	248.1**	43.89**	1.00	0.03	4.00**	0.53	90.3**	575*
Protein	1				0.06	0.00	547*	0.05	0.02	973*	33.1	4.20	0.11	0.15	0.52	0.04	83.9**	84
E x P	1				0.20*	0.30	378*	0.04	0.08	53	3.1	0.36	0.38	0.01	0.90	0.11	31.8	258
Strain	1	0.17*	1.19**	9,324**	0.01	0.24	1186**	0.03	0.64	4304**	52.6	12.96*	9.92**	0.85**	15.01**	0.38	132.9**	4482**
Sex	1	1.18**	1.56**	295	0.15*	3.14*	2579**	0.49**	2.81*	562*	36.0	0.16	1.10	0.14**	7.42**	5.20**	182.3**	2051**
Rat. x Str.	3	0.27**	0.38*	120	0.01	0.29	499*	0.04	0.16	134	8.2	2.46	0.29	0.01	0.43	0.09	17.9	79
Rat. x Sex	3	0.00	0.01	2	0.00	0.02	178	0.00	0.01	57	2.9	1.16	0.99	0.01	0.05	0.11	5.0	56
Str. x Sex	1	0.29**	0.18	175	0.29**	0.95	144	0.01	0.03	32	16.0	8.85	0.03	0.01	0.40	0.01	6.8	4
Error	51	0.04	0.05	238	0.03	0.13	27	0.02	0.11	55	26.5	2.49	0.48	0.02	0.36	0.14	8.6	84

[1]In the growing period in Expt. 1 ration, d.f. is 3 and error d.f. is 37, while in Expt. 2 ration d.f. is 1, and error d.f. is 57. One pig died in the finishing period in Expt. 1 and no carcass information was obtained on still another, so error d.f. is reduced to 20 in the finishing period and 19 for carcass characteristics. Error d.f. in the growing period for av. daily feed and feed per lb. gain in Expt. 1 is 11 and in Expt. 2 is 9, while the corresponding figures in the finishing period are 7 and 3 for Expt. 1 and 2 respectively.

[2]Adjusted by covariance for hot carcass weight. Adjustment was made for backfat, belly score and Advanced Registry score only in Experiment 2. Error d.f. is 50.

TABLE 9.—SIGNIFICANT INTERACTIONS IN EXPERIMENT 2

Strain		T(LY)	Y(LY)
Average daily gain, lb. Growing period	HE–HP	1.76	1.73
	LE–HP	1.56	1.80
	Males	1.73	1.97
	Females	1.59	1.56
Finishing period	Males	1.84	1.72
	Females	1.61	1.76
Average daily feed, lb. Growing period	HE–HP	5.7	4.8
	LE–HP	5.1	4.8
Feed per lb. gain, lb.			
Finishing period	HE–HP	4.04	3.75
	HE–LP	4.32	3.90
	LE–HP	4.27	4.18
	LE–LP	4.20	4.29

on efficiency of feed utilization in the growing period, it assumed a major role in the finishing period with HE rations being more efficient than LE rations in both experiments. Although the influence of protein level on efficiency of feed utilization in the finishing period was not as pronounced as in the growing period, HP rations alone and in combination with HE rations significantly lowered the feed requirement in Experiment 2 while a similar trend in Experiment 1 was not significant.

Female pigs required less feed per pound of gain than male pigs in the finishing period. This may be a reflection of the lower fat content of the female carcasses. In the earlier growing period this sex difference did not exist. The Y(LY) pigs were more efficient at all stages than were the T(LY) pigs. This too may be explained largely on the basis of fatness of the carcasses, although other metabolic differences probably exist between strains as well as between sexes. No noticeable or consistent differences in feed wastage between the two strains were apparent, with wastage being low in all cases.

Except for those listed in Table 9, no significant first order interactions for gain, feed intake and feed efficiency among rations, strains and sexes were present.

Carcass Characteristics

Pigs receiving HE rations had a higher dressing percentage by an average of 2.3 per cent than pigs fed LE rations. This resulted in higher hot carcass weight for pigs fed HE rations, although this difference was significant only in Experiment 2.

HE rations generally had an adverse effect on carcass measurements especially average backfat, loin area, percentage ham and Advanced Registry belly score and total score. Most of the difference in average

backfat resulting from energy level in the ration was associated with differences in hot carcass weight in Experiment 2 but not in Experiment 1. Pigs fed HE rations had smaller areas of loin than those fed LE rations but this difference was significant only in Experiment 1.

Protein level in the ration had no statistically significant effect on carcass characteristics. However, area of loin decreased progressively in pigs fed HP, MP and LP rations. A similar trend existed for belly score and total A.R. score. The results are, therefore, not incompatible with the general observations [for example Ashton *et al.*(3)], that higher protein levels in a ration favourably influence carcass leanness although the protein level used in the present trials did not result in statistically significant effects. Neither protein nor energy levels in the ration resulted in any difference in carcass length.

Energy and protein level in the ration seemed to affect carcass quality independently. There was little evidence from these trials of an interaction of energy and protein levels on carcass quality measures and the apparent trend for HE-HP pigs to have comparable carcasses to LE groups probably resulted from the beneficial effect of protein partially offsetting the deleterious effect of energy.

Female carcasses were superior to male carcasses with a lower backfat thickness, and increased percentage ham, area of loin, belly score and total A. R. score. The sexes did not differ appreciably in length of carcass and in Government grades.

In Experiment 1, strain differences in carcass quality were negligible except that the Yorkshire pigs had a 1 per cent higher dressing percentage than the Lacombe-Yorkshire pigs. These two strains have been observed to have similar carcass characteristics in other studies at the University of Alberta. In Experiment 2 the Y(LY) strain excelled the T(LY) strain in all carcass characteristics except dressing percentage where the Y(LY) was inferior to the T(LY) strain. This difference in carcass quality was evident even though no difference occurred in rate of gain during the experimental period, indicating that rate of gain is not necessarily associated with carcass quality when strains are being compared.

With one exception, there were no significant first order interactions for carcass characteristics among rations, strains and sexes, indicating that strain and sex differences in carcass quality could be evaluated with equal accuracy over the rather wide range of energy and protein levels used in these experiments.

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CO-RAL[1] SPRAYS FOR SYSTEMIC CONTROL OF THE CATTLE GRUBS *HYPODERMIC BOVIS* L. AND *H. LINEATUM* DE VILL.[2]

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ABSTRACT

Aqueous suspensions of 0.25, 0.5, and 0.75 per cent (weight on volume) of CO-RAL in wettable powder were sprayed on Hereford calves for the control of prehypodermic cattle grubs. Two types of CO-RAL sprays were used, one with anionic and the other with a combination of anionic and non-ionic surfactants. They were applied at pressures of 50 and 400 lb. per square inch, and when the lower pressure was used the spray gun was equipped with a hair rake to ruffle the hair. One gal. of spray per head was applied once to the backs and sides of each calf. Sprays containing 0.75 per cent CO-RAL reduced the number of grubs in treated calves by 86 and 90 per cent ($P > 0.01$) as compared with the number in the untreated group. There was no difference in larvicidal effects between 0.25 and 0.5 per cent sprays, both of which reduced the number of grubs by 60 to 70 per cent. Neither the surfactants used nor the pressures employed had any effect on larvicidal properties of CO-RAL sprays.

None of the treated calves showed signs of organophosphorous poisoning, but an outbreak of shipping fever was noticed in the herd. Question is raised if the stress of CO-RAL sprays, which are cholinergic in effect, lowered the resistance of the treated calves to shipping fever, against which they had been vaccinated previously.

INTRODUCTION

Organosphosphorous compounds have been used as systemic insecticides for the control of crop insects for almost a decade (2), but their application for control of the insect parasites of livestock on a large scale is more recent. CO-RAL is one of these compounds, and Smith and Richards (6) first used it for the control of the hypodermic stages of *Hypoderma lineatum* de Vill. as a wash scrubbed on the backs of infested cattle. They found it 100 per cent and 88 per cent effective at 1.0 per cent and 0.5 per cent concentrations, respectively. Later, Roth and Eddy (5) found the 0.5 per cent wash also 100 per cent effective against the same stages of the parasite. They also obtained complete control of hypodermic stages of *H. bovis* L. with CO-RAL sprays at 0.5 per cent concentration applied at 350-lb. pressure. These authors did not report any prehypodermic grub control, which was first noted by Brundrett *et al.* (1) against *H. lineatum* and later confirmed by Graham (4) against both *H. lineatum* and *H. bovis*.

During the winter of 1957-58, CO-RAL formulations were used as sprays and as an ointment for the systemic control of the prehypodermic stages of *H. lineatum* and *H. bovis* in southern Alberta. At the time of treatment the cattle had a heavy hair coat, which was likely to hinder the spray reaching the skin and to interfere with the absorption of CO-RAL by the host. Surface active agents and physical and mechanical means

[1]Also known as "Bayer 21/199" and supplied by Chemagro Corp., Kansas City, Missouri. The chemical name is O,O-diethyl O-(3-chloro-4-methyl-7-coumarinyl) phosphorothioate.

[2]Contribution from Veterinary-Medical Entomology Section, Canada Department of Agriculture.

were employed, therefore, to increase the wetting of the hair and skin. CO-RAL was used in the form of an ointment also, since spraying in winter may predispose young stock to chilling and respiratory diseases.

The objectives of the experiment were to determine (a) the CO-RAL concentrations that were most effective against prehypodermic grubs but harmless to the host, and (b) the influence of the surfactants and of the methods of application employed on the effectiveness of the chemical as a systemic insecticide.

In another experiment we determined on autopsy (a) the effects of CO-RAL sprays applied to the entire body of a calf and (b) any intercurrent infections and infestations in the experimental herd.

MATERIALS AND METHODS

Experiment No. 1

Two hundred Hereford calves, 6 to 7 months old, and weighing approximately 350 to 400 pounds, were selected at random from a ranch herd in southern Alberta where studies on regional population densities of warble flies had shown a heavy natural infestation. From these studies it had been determined that a sample size of 20 calves per experimental group was adequate for this experiment. This was calculated at the level of 90 per cent probability and 25 per cent error by the formula $n_o = \left(\frac{ts}{d}\right)^2 (3)$. Thus, the animals were randomly divided into ten groups of 20 calves each. Eight groups were used for spray treatments and one for ointment treatment, and one was left untreated. The calves had been weaned and vaccinated against shipping fever and black leg 3 weeks before treatment with the insecticide.

A wettable powder of CO-RAL containing 25 per cent of the active ingredient was used to prepare the spray formulations, which were applied to the backs and sides of the calves at the rate of 1 gallon per head by means of a power sprayer equipped with a 3-nozzle gun with 4/64-inch discs. The CO-RAL ointment was made with lanolin and soya bean oil base and was applied to the sides of the neck at the rate of 3 ounces per calf. The following formulations of CO-RAL were applied once to the different groups of calves:—

(1) 0.75 per cent spray with anionic and non-ionic surfactants at 400-lb. pressure p.s.i.
(2) 0.75 per cent spray with anionic surfactants at 400-lb. pressure p.s.i.
(3) 0.5 per cent spray with anionic surfactants at 400-lb. pressure p.s.i.
(4) 0.5 per cent spray with anionic and non-ionic surfactants at 400-lb. pressure p.s.i.
(5) 0.5 per cent spray with anionic surfactants at 50-lb. pressure p.s.i. applied with a gun equipped with a hair rake to ruffle the hair.
(6) 0.5 per cent spray with anionic and non-ionic surfactants applied as in (5).
(7) 0.25 per cent spray with anionic surfactants at 400-lb. pressure p.s.i.
(8) 0.25 per cent spray with anionic and non-ionic surfactants at 400-lb. pressure p.s.i.
(9) 4.0 per cent ointment.

These treatments were applied on December 13 and 16, 1957. At that time grubs were not evident in the backs of any of the calves. The calves were examined weekly, from January 13 to May 6, 1958, for hypodermic grubs, which were squeezed out and recorded separately from each

group. The percentile difference between the numbers of grubs in treated and untreated groups was the measure of the efficacy of the treatment. The significance of the larvicidal effects of the various treatments and factors was assessed by analysis of variance.

Experiment No. 2

Another group of 14 calves taken at random from the same herd was divided at random into two groups of 6 each for treatment; the remaining 2 calves were not treated. The two groups of 6 were sprayed on December 17, 1957, with 1 gallon per head of CO-RAL applied to the entire body at a pressure of 400 pounds by the same type of equipment as used in Experiment No. 1. One group was treated with sprays containing anionic surfactants and the other with a combination of anionic and non-ionic surfactants.

The 2 untreated calves were slaughtered on December 18, and a post-mortem examination was carried out for warble and helminth infestations and for gross pathological lesions. Two calves from each of the two sprayed groups were slaughtered and autopsied 1 week after treatment and at subsequent weekly intervals. Their carcasses were carefully examined for warble larvae and pathological lesions that might have been caused by CO-RAL.

RESULTS AND DISCUSSION

Experiment No. 1

Systemic effects of CO-RAL sprays

The numbers of hypodermic grubs squeezed from the treated groups of calves were taken to represent the hypodermic grubs that survived the effects of CO-RAL and to be inversely proportional to the efficacy of the respective treatments (Table 1). In all groups sprayed with CO-RAL the numbers of hypodermic grubs were significantly lower ($P<0.01$) than in the untreated group and in the group treated with CO-RAL ointment.

The numbers of hypodermic grubs were low in January in all the experimental groups but increased in February and stayed at high levels through March and April, followed by a sudden drop in May. This suggested that treatment with CO-RAL did not interfere with the development of the prehypodermic grubs that survived the treatment.

The number of surviving grubs was significantly lower ($P<0.05$) in the 40 calves sprayed with 0.75 per cent concentration than in the calves sprayed with 0.5 per cent and 0.25 per cent CO-RAL. There was no difference in larvicidal efficacy between 0.5 per cent and 0.25 per cent CO-RAL.

Two groups of 80 calves each were treated, one group with sprays containing anionic surfactants and the other with sprays containing anionic and non-ionic surfactants. No significant difference was noticed in the number of hypodermic grubs in the two groups. However, in the spray tanks the anionic surfactants caused a great deal of foaming, which was reduced when the combination of anionic and non-ionic surfactants was used.

TABLE 1.—NUMBER OF CATTLE GRUBS SURVIVING THE SYSTEMIC EFFECT OF CO-RAL FORMULATIONS, EACH APPLIED TO A SEPARATE GROUP OF 20 CALVES IN DECEMBER, 1957, IN SOUTHERN ALBERTA

CO-RAL treatments applied	No. of hypodermic grubs collected from experimental calves in 1958					Mean no. of grubs per calf with standard error[1]	Estimated percentage mortality in prehypodermic gru s
	January	February	March	April	May		
1. 0.75% spray with anionic and non-ionic surfactants at 400 lb.	1	3	27	34	0	3.4 ± 1	86
2. 0.75% spray with anionic surfactants at 400 lb.	0	6	21	17	1	2.3 ± 0.9	90
3. 0.5% spray with anionic surfactants at 400 lb.	2	36	59	54	9	8.4 ± 2.5	64
4. 0.5% spray with anionic and non-ionic surfactants at 400 lb.	7	22	79	56	7	8.6 ± 1.7	64
5. 0.5% spray with anionic surfactant at 50 lb. with hair rake	1	13	69	47	10	7.0 ± 1.5	70
6. 0.5% spray with anionic and non-ionic surfactants at 50 lb. with a hair rake	2	51	51	31	6	7.8 ± 1.8	67
7. 0.25% spray with anionic surfactants at 400 lb.	0	21	51	61	8	7.4 ± 1.6	68
8. 0.25% spray with anionic and non-ionic surfactants at 400 lb.	1	21	88	41	6	8.2 ± 2	65
9. 4% CO-RAL ointment	4	49	169	177	23	22.2 ± 3.5	6
10. Untreated	40	141	148	123	18	23.5 ± 6.6	—

[1]Significantly lower for all spray treatments No. 1 to 8 than for the untreated at 1% level. In addition, the number of grubs was significantly lower for the first two treatments than for the next six at 5% level.

The 0.5 per cent concentration reduced the number of surviving grubs by 64 per cent when applied at 400-lb. pressure and by 68.5 per cent at 50-lb. pressure in conjunction with a hair rake. Thus, these two methods of application were equally effective in allowing the sprays to penetrate the hair coat to the skin. The low pressure treatments were laborious and time-consuming. It took approximately 12 seconds to spray each calf at the higher pressure and 45 seconds at the lower.

Systemic effects of CO-RAL ointment

The CO-RAL ointment had no systemic effect on the prehypodermic grubs. It is possible that the ointment stayed on the long hair, which prevented its contact with the skin and absorption into the host's system.

Tolerance to CO-RAL in sprayed calves

No signs of organophosphorous poisoning were noticed in any of the treated calves, but approximately 1 month after treatment a mild outbreak of shipping fever was noticed in the herd. The calves were left undisturbed and were not examined individually to prevent further deterioration in the condition of the sick animals. It was not possible, therefore, to determine which of the experimental groups was suffering from shipping fever. All the sick calves recovered without medication.

The outbreak of shipping fever in the herd raised the question of indirect injurious effects of CO-RAL. This outbreak cannot be linked positively with CO-RAL sprays, yet the incidence of a disease in which stress is an exciting factor cannot be overlooked, particularly in a vaccinated herd. The clinical examinations and autopsy findings reported below in Experiment No. 2 suggested that the calves had some pathological involvement of their respiratory tracts, which increased their susceptibility to shipping fever. The stress of CO-RAL sprays perhaps further lowered their resistance to the causal organism of shipping fever, which then became actively pathogenic. Further work is in progress on this aspect of CO-RAL sprays.

Experiment No. 2

No gross pathological lesions that could be ascribed to CO-RAL were noticed on post-mortem examination of the carcasses of the treated calves. However, 1 of the 4 calves slaughtered 2 weeks after spraying showed congestion, hepatization, and consolidation in the lower part of the apical lobe of the right lung. Similar lesions were noticed in one of the untreated calves. A total of 26 dead and 92 live prehypodermic grubs were collected from the 12 sprayed calves, and 10 live grubs were collected from the 2 untreated ones. All the grubs were found in the vertebral canal embedded in the fat surrounding the spinal cord except one, which was noticed on the external surface of the esophagus. Areas of congestion and serosanguineous infiltration marked the location of the larvae.

A mean of 7.7 $\pm$ 2.5 (standard error) grubs per calf were collected from the 12 sprayed calves; this was comparable to 8.5 $\pm$ 1.2 (standard error) grubs per calf that survived treatment with 0.5 per cent CO-RAL at 400-lb. pressure in Experiment No. 1. It may be argued that some of these 92 larvae, having been exposed to CO-RAL, would have died later

if their hosts had survived and that the actual number of the larvae reaching the hypodermic stage would have been reduced. It should be emphasized that the number of larvae collected on autopsy did not represent the actual number of living larvae in the carcasses, as some must have escaped detection due to their small size and wide distribution. However, these figures are presented to indicate the larval mortalities observed in the two experiments.

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DIFFERENCES IN MARKET QUALITY BETWEEN BROILER STRAINS AS EVALUATED BY MARKET GRADING[1]

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ABSTRACT

Chicks from 10 broiler strains were randomly allotted and reared at three farms. At 10 weeks of age a random sample consisting of 60 birds of each strain, with an equal number of each sex, was taken at each farm, slaughtered and market graded. At each farm, an official inspector graded the birds according to the standards of the Canada Department of Agriculture. Each bird was graded for the four grade factors: conformation, fleshing, fat and dressing.

The number of birds in each grade class was not independent of farm, sex or strain. The 10 strains, ranked on grade scores, tended to rank in the same order at each farm, although the agreement was better for some grade factors than others, and was better when based on males than on females. On a strain rank basis, the grade scores for any one grade factor were not, in general, indicative of the scores for any other grade factor. Also on a strain rank basis, there was a high positive correlation between breast angle and grade scores for fleshing: body weight was not correlated with grade scores for any of the four grade factors, with the possible exception of conformation in the case of males.

INTRODUCTION

In dealing with market quality in poultry, many investigators have considered objective descriptions and measures of quality to be far more suitable for investigational and breeding purposes than a visual or subjective evaluation of quality (1). As desirable as this approach is, there are quite a few practical difficulties involved in evaluating quality on a strictly objective basis even for research investigation, and in commercial practice visual evaluation of market quality is practised exclusively.

It is of some interest to note, however, that, although grading of market poultry has been in effect in Canada for a number of years, there have been few studies relating to market grading. This is especially true with respect to studies relating market grading to breeding. There is a need for such studies since grade standards and the application of these standards indicate what market quality factors are considered in evaluating quality in commercial practice, and of equal importance to the commercial breeder is the fact that grade price differentials represent differences in economic returns. Whether a breeder would be justified in attempting to breed for improved market quality would depend to what extent these market quality factors are inherited and on their economic importance.

The primary objective of this study was to investigate differences in market quality between commercial broiler strains, as evaluated by market grading.

[1]Contribution No. 3, Animal Research Institute, Research Branch, Canada Department of Agriculture, Ottawa, Ont.

MATERIALS AND METHODS

Ten strains of broilers were used in this study. Eight of these strains were obtained from commercial breeders while the remaining two were developed at the Central Experimental Farm, Ottawa. The growth performance of these ten strains has been reported in a previous paper (7).

Chicks from the ten strains were hatched on the same date at one location, Ottawa. At hatching, equal numbers of chicks from each strain were randomly allotted to three farms (Experimental Farms of Canada Department of Agriculture) at Charlottetown, Prince Edward Island, Lethbridge, Alberta, and Ottawa, Ontario. The chicks assigned to Charlottetown and Lethbridge were shipped by air on the date of hatching.

As far as possible, uniform management, feeding programs, and rations were used at each of the three farms. All rearing procedures used were based on commercial practices used in rearing broilers.

TABLE 1.—NUMBER OF BIRDS CLASSIFIED ACCORDING TO MARKET GRADE FOR THE FOUR GRADE FACTORS BY SEX[1]

Sex	Grade class	Grade factor			
		Conf.	Flesh.	Fat	Dress.
Males	Sp.	770	192	32	460
	A	117	622	557	330
	B	12	85	308	102
	C	0	0	2	7
	D	1	1	1	1
Females	Sp.	793	307	65	459
	A	90	546	657	324
	B	11	43	175	92
	C	5	3	2	24
	D	1	1	1	1

[1]Grading data based on a total of 1800 birds, each bird graded for each grade factor

TABLE 2.—RANGE BETWEEN STRAINS AND MEANS FOR FARMS OF GRADE SCORES FOR THE FOUR GRADE FACTORS[1]

Sex	Farm	Grade factor							
		Conf.		Flesh.		Fat		Dress.	
		Range[2]	Mean[3]	Range	Mean	Range	Mean	Range	Mean
Males	Ott.	12	111	15	98	16	82	22	85
	Leth.	2	119	17	86	18	86	44	111
	Char.	11	115	23	97	22	75	43	108
Females	Ott.	13	112	22	102	7	87	32	82
	Leth.	1	120	9	90	19	90	54	109
	Char.	12	115	18	104	16	81	40	111

[1]See text for definition of grade score
[2]Difference in grade score between highest and lowest of 10 strains
[3]Mean grade score of 10 strains

The chicks of the different strains were reared intermingled throughout the test. At 10 weeks of age, at each of the three farms, 30 birds of each sex were randomly selected from each strain for determination of individual body weight and breast angle [West Virginia Angle Meter, Clark and Cunningham, (2)]. These birds were also scored for back feathering and for the presence of crooked keels and breast blisters before being slaughtered. Within 1 to 2 days after slaughtering, the birds were individually graded by a Poultry Products Inspector of the Canada Department of Agriculture.

The birds were never separated by strain or sex at any stage of the experiment. The birds were taken at random for weighing, measuring, processing and grading.

RESULTS AND DISCUSSION

The grading system employed for poultry in Canada is commonly referred to as factor grading. Four factors are considered, namely, conformation, fleshing, fat, and dressing. Each bird is assigned one of five grades, *Sp.* (special), *A*, *B*, *C* or *D*, for each grade factor. The final or market grade for the bird is the lowest grade it is assigned for any of the four factors.

The grading data are presented in two ways. In Table 1, the number of birds in each grade class (*Sp.*, *A*, *B*, *C* and *D*) are shown for each of the four grade factors. The data were coded by assigning numerical values of 4, 3, 2, 1 and 0 to the five grade classes, *Sp.*, *A*, *B*, *C*, and *D*, respectively. The maximum possible grade score, or sum of these coded values, for one sex of a particular strain at one farm would be 120. The range of grade scores between the highest and lowest of the ten strains, and the means of the strain grade scores for each farm, by sex, are presented in Table 2.

It is quite apparent (Table 1) that the grades were somewhat higher for some grade factors than others. Nearly all birds were placed in the two top grade classes (*Sp.* and *A*) for conformation, whereas a rather large percentage of the birds were graded *B* for fat.

TABLE 3.—CHI-SQUARE VALUES FOR GRADING DATA CLASSIFIED AS TO GRADE CLASS AND SEX; FARM; STRAIN

Data classified	Sex	Grade factor			
		Conf.	Flesh.	Fat	Dress.
		(1)[1]	(2)	(2)	(2)
Sex	—	2.6	42.8†	129.8†	0.3
		(2)	(4)	(4)	(4)
Farm	—	158.0†	247.0†	195.4†	39.7†
		(9)	(18)	(18)	(18)
Strain	M	23.5†	138.0†	93.9†	279.5†
	F	10.9	65.6†	69.7†	274.3†

[1]Degrees of freedom
†$P < 0.01$

TABLE 4.—RANK CORRELATIONS AMONG MARKET GRADE SCORES OF 10 STRAINS AT THREE FARMS

Sex	Grade factor			
	Conformation	Fleshing	Fat	Dressing
Males	.72*	.89†	.80†	.81†
Females	.25	.69*	.73*	.43

*P <0.05
†P <0.01

TABLE 5.—RANK CORRELATIONS BETWEEN GRADE SCORES OF (10 STRAINS) MALES AND FEMALES

Grade factor	Correlation
Conformation	.39
Fleshing	.77†
Fat	.78†
Dressing	.49

†P <0.01

Farm, strain and sex all had an influence on grades (Table 2). It is of interest that the highest scores in all grade factors were not obtained at any one farm. On the other hand, females tended to score higher than males and for the most part were equal to or better than the males in all factors at all farms.

From the chi-square values (Table 3) it was concluded that, for these data, the number of birds in each grade class was not independent of farm, strain or sex (with a few exceptions for conformation and dressing as noted in Table 3).

It would not be unreasonable to expect differences between farms in the grading results since differences between farms have been demonstrated by Merritt and Gowe (7) for such quantitative traits as body weight and other body measurements. Differences between farms are also no doubt due in part to the graders. To what extent differences between graders account for these farm differences cannot be determined from these data. The important question, however, is not whether differences between farms existed but whether the strains were evaluated in the same relative order at each of the three farms. To examine this question, the strains were ranked, within each farm and sex, on the basis of grade score and the rank correlations* among the 10 strains at the three farms were obtained for each grade factor. It is clear from the correlation values shown in Table 4 that, for the most part, there was a substantial measure of agree-

*The rank correlation methods used in this study were based on those given by Kendall (5). In the case of two rankings, Spearman's rank correlation was used. In the case of m(m> 2) rankings, the rank correlation coefficient is sometimes called coefficient of concordance. In this study, however, all correlations, for the sake of simplicity, are referred to as rank correlation coefficients. Table 4 is the only case in which m rankings are involved. For combining data, sums of ranks were ranked rather than sums of grade score values.

TABLE 6.—RANK CORRELATIONS BETWEEN GRADE SCORES OF 10 STRAINS FOR ALL PAIRS OF GRADING FACTORS

	Sex	Fleshing	Fat	Dressing
Conformation	M	.43	.24	−.02
	F	.77†	.10	.73*
Fleshing	M		.25	−.09
	F		−.22	.60
Fat	M			.16
	F			.10

*P <0.05
†P <0.01

TABLE 7.—RANK CORRELATIONS BETWEEN GRADE SCORE (FLESHING) AND VARIOUS BODY MEASUREMENTS OF STRAINS

Farm	Body weight		Breast angle		Keel length		Shank length	
	M	F	M	F	M	F	M	F
Ottawa	.12	.27	.93†	.94†	−.21	−.32	−.26	−.31
Lethbridge	−.03	.15	.81†	.70*	−.54	.36	−.44	.03
Charlottetown	.1	−.08	.97†	.63*	−.69*	−.17	−.38	−.09
Combined farms	−.03	−.02	.89	.86	−.66	−.21	−.42	−.20

*P <0.05
†P <0.01

ment in the order in which the strains ranked at the three farms. It is of some interest to note that the correlations are slightly higher for all four grade factors for males than for females. This is in agreement with the general observation that, in market grades, greater differences are evident among males than females.

Combining the data from the three farms, strain ranks based on male scores were correlated with strain ranks based on female scores for each of the four grade factors. As seen in Table 5 the correlations for conformation and dressing were not found to be significant. This was not unexpected since the correlations (Table 4) between farm strain ranks for these two grade factors were not significant when based on females.

To determine whether the grading of the strain for one factor was any indication of the grading for any other factor, rank correlations were computed between all pairs of grade factors. These correlations are presented in Table 6. As seen in the table, it is apparent that, for the most part, there was almost no agreement in the order in which the strains ranked for one grade factor and their ranking for any other factor.

It is well known that there are differences among strains for what may be called market quality traits. Among those traits which can be readily measured are breast width and certain body measurements such as

TABLE 8.—RANK CORRELATIONS BETWEEN GRADE SCORE AND BODY WEIGHT OF STRAINS

Grade factor	Males	Females
Conformation	−.70*	−.08
Fleshing	−.03	−.01
Fat	−.26	.02
Dressing	−.09	.21

*P <0.05

keel and shank length. On a strain rank basis, correlations were computed between fleshing grade scores and each of these traits as well as for body weight. As seen in Table 7, the rank correlations between breast angle and fleshing scores were found to be significant. The correlations with body weight were relatively low and inconsistent in sign, whereas those with shank and keel lengths, although not significant, were in general somewhat higher and mostly negative.

Market grades for conformation are primarily based on the presence and the degree of such defects as crooked keels and breast blisters. Although observations on these defects were made on the live birds, the data, on a strain basis, did not reveal any significant relationship between the incidence of these defects and market grades for conformation. Since relatively few birds were graded B for conformation (Table 1), it may be that these defects are relatively unimportant in birds of broiler weight. It was felt, however, that observations on these defects were not as carefully or as critically taken as they might have been in this study. Hyre (4) has shown that the tendency towards deformed keels is inherited, although he concluded that the expression of this condition depended on whether the birds were allowed access to roosts during the growing period. Shoffner and Canfield (9) have reported breed differences in keel defects (crooked keels and breast blisters) in males at 6 months of age with the greatest incidence of these defects in birds reared with roosts. Since commercial broilers are not usually reared with roosts, keel defects do not appear to be at the present an important cause of downgrading in broilers. The problem of keel defects, especially breast blisters, is of some importance, however, in birds reared to heavier weights even when reared without roosts, as shown by Shoffner and Canfield (9). This problem could be profitably investigated further.

Feathering scores obtained in this study (based on the completeness of back feathering) were not found, on a strain rank basis, to be correlated with grade scores for dressing. It was felt, however, that the scoring of the birds as to the condition of the back feathering was not as carefully carried out in this study as it might have been. This problem also could be investigated further. One strain had relatively low grade scores for dressing. This strain was largely responsible for the wide range in grade score values between strains as shown in Table 2. This was the only strain with other than white plumage. The other strains were all white or nearly white in plumage colour. This would indicate that dark plumage results in serious down-grading for dressing. However, this strain also showed rather poor feathering.

It has been observed, both by Lerner *et al.* (6) and Frischknecht and Jull (3), that the heaviest birds tend to have the highest market grades. These findings were based on United States grade standards in effect at the time the cited studies were carried out. Correlations between strains ranked for body weight and each of the four grade factors (Table 8) do not, with the possible exception of conformation in the case of males, indicate that this relationship exists in these data. These correlations are, of course, on a strain rank basis, but similar analyses of such Canadian market grading data on an intra-strain basis at this institution (8) support these conclusions. These findings are of some interest as Lerner *et al.* (6) concluded from the results of their study that there was little basis for assigning economic weightings to market quality traits since it appeared, to some degree, that in the grading procedures market quality *per se* was not being evaluated.

The problem of procedures to follow and techniques to use in breeding for market quality in poultry is quite complicated. The preceding analyses do, however, indicate that strain differences in market quality, measured in terms of market grades, do exist. It appears that, in testing and evaluating strains or in undertaking to improve the market quality of a given strain, a breeder would be well advised to secure market grading data, preferably on a factor basis, on the strain or strains of interest to him. This information would be of immense value in establishing what factors need the greatest attention. At the same time, the economic significance of improvement of market quality can be readily evaluated from current market prices.

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A COMPARISON OF DIFFERENT METHODS OF WEIGHING AND SAMPLING OF MILK YIELDS

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ABSTRACT

This investigation was performed for the purpose of determining the precision in terms of variation and accuracy of a metering device and spring scales for the weighing of milk for production testing and to ascertain also the precision of butterfat tests determined from meter samples. Springless scale weights and conventional sample tests served as standards of accuracy. The study was conducted as a factorial arrangement in a split-plot design. The factors concerned were: four breeds of cows, three levels of production, and three methods of measuring milk production. Milk production was measured for 4 consecutive days in each of 6 consecutive weeks with daily Babcock tests being conducted on all milk samples.

The average daily per cow deviation of the meter weights, and of the spring scale weights, from the control scale was −0.09 and +0.11 lb. of milk respectively, with the difference being statistically significant but non-significant in a practical sense. Levels of production, breeds and levels × breeds did not significantly affect the meter sample weights or butterfat tests.

On an over-all basis, the meters met the American Dairy Science Association accuracy requirement on both the 0.5 lb. and the 3 per cent tolerance levels. The spring scales, on the 0.5 lb. tolerance basis, failed to give weights within the required accuracy. Ninety-five per cent of the meter sample tests were within 0.2 per cent of the conventional sample tests.

INTRODUCTION

The installation of pipeline milkers in the stanchion barn as well as in the milking parlor is a step toward greater labour efficiency and milking convenience on modern dairy farms. While the pipeline milker is easing the milking operation, it is creating new problems in other areas. The weighing and sampling of each cow's milk, by means of present methods, is not easily accomplished under the pipeline system of milking. An accurate yield of milk for each cow and a representative sample of this milk for testing purposes can be obtained if the regular milker pails are used on testing days instead of the pipeline. These pails are, however, generally traded in, with the result that the farmer does not have a means of weighing and sampling the milk from each cow. The change in routine from pipeline to milker pails on test days may also disturb the cows, resulting in abnormal weights and tests.

Another system of weighing and sampling each cow's milk under pipeline conditions has been to secure special holding jars that fit into the system. Senger (1) reports that this method has proven unsatisfactory, not only from the point of view of accuracy of weights but particularly because of the difficulty experienced in obtaining a representative milk sample. Senger (1) also reported that air should be bubbled through the milk in these holding jars for one second for each pound of milk, if

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butterfat tests are to check with samples from thoroughly mixed milk. If no such provision is made, samples drawn without additional mixing have been shown to give inaccurate estimates of percentage fat.

In an effort to combine convenience, simplicity and accuracy of weighing and sampling, a metering device referred to as the "Milk-O-Meter" was developed commercially and placed on the market. Tests on earlier models of this metering device indicated that milkings of fast-milking, high-producing cows tended to be underweighed [Senger (1)]. The butterfat tests obtained from the Milk-O-Meter, however, have generally been in satisfactory agreement with those obtained from conventional sampling.

The main objectives of this study were: (a) to compare the variability of milk yields and butterfat tests; (b) to compare the estimates of milk production as determined by the Milk-O-Meter and the commonly used method of weighing milk by dairy farmers and official testing services with a standard springless scale; and (c) to compare the estimates of percentage butterfat of samples from the Milk-O-Meter with those sampled in the conventional manner.

MATERIAL AND METHODS

This study was conducted as a factorial arrangement in a split-plot design. The factors considered were: four breeds of cows—Holstein (H), Ayrshire (A), Jersey (J) and Guernsey (G); three levels of production—high (h), medium (m) and low (l); and three methods of measuring milk production—Milk-O-Meter (M), dairy spring scale (S) and a springless scale (T). The individual cows were classified as to level of production according to their average daily production during the week prior to the commencement of the experiment. Milk production was measured for 4 consecutive days in each of 6 consecutive weeks. Thus, there were 12 cows represented with a total of 24 milk yields being recorded for each cow for each method of weighing.

The random allotment of the cows on the two sides of the milking alley yielded the following arrangement:

SIDE I			SIDE II		
Cow No.	Breed	Production Level	Cow No.	Breed	Production Level
1	H	m	7	J	h
2	H	h	8	G	h
3	A	m	9	J	l
4	H	l	10	A	h
5	A	l	11	J	m
6	G	l	12	G	m

Because of practical considerations, it was necessary at each milking to have a different Milk-O-Meter on the milking line of each group of 6 cows. In order to allow the variation among Milk-O-Meters to be expressed, a different pair of meters was used each week. A different spring scale was employed each week, but only one springless scale was used during the entire period. Of the six spring scales used, three were new and three had been used for several years.

The Milk-O-Meters were of the latest design with the sampling devices of the stainless steel type. The spring scales were of the type commonly used as dairy scales. The springless scale was considered as a standard and had been checked for accuracy prior to the commencement of this experiment.*

Milking was done with the milker pail type of installation. It should be realized that it was impossible to test the meters under identical conditions that would exist in practice when the pipeline milking system is being followed. In order to collect the milk from each cow the standard milker pail had to be used so that weights by the dairy spring scale and springless scale could be recorded. The actual system used in this experiment is illustrated in Figure I. The milk flowed from the cow through the meter and then into the milker pail rather than into the pipeline. This deviation from the actual situation could possibly influence the results but probably not sufficiently to render the results invalid.

Each pair of Milk-O-Meters, operating simultaneously, was employed in the following manner during the entire experimental period. Each meter was used for one row of cows for two successive milkings, and then was switched to the opposite row for the following two milkings. By following this procedure, the same cow's milk was weighed by one meter on the first and third day of the week and was weighed by the other meter on the second and fourth day. The order of milking the cows was continually changed, with the idea of removing any bias which might arise from following a constant order of milking.

At the completion of milking a cow, the following order of operations was performed:

1. The teat-cups were removed with the vacuum still on.
2. The Milk-O-Meter readings were recorded and are referred to as an untripped weight.
3. The rocker was tripped once. The reason for tripping was to prevent crediting the next cow milked with any of the milk from the previous cow which might have been left in one section of the rocker. This meter reading will be referred to as a "tripped weight".
4. The meter sample was taken.
5. Each cow's milk was weighed on the spring scale and the standard scale. The spring scale weights were recorded to the nearest tenth of a pound and the springless scale weights to the nearest ounce.
6. A milk sample was drawn from the pail by means of the conventional sampling method.

Once a day the Milk-O-Meter samples (MS) were weighed and recorded with the Babcock test being conducted on these samples as well as on the samples collected by the conventional method (CS). The meter sample

* The springless scale was checked and approved by officials of the Canada Department of Trade and Commerce, Standards Division.

FIGURE 1. Milking arrangement illustrating direction of milk flow from claw through meter to milker pail.

(MS) collection was conducted in two different ways, each for three of the 6 weeks of the experiment. One method consisted of collecting all of the milk extracted by and retained in the sampling device during the milking of each cow. The size of these samples was generally in proportion to the volume of milk produced by an individual cow. The second method was that recommended by the manufacturer of the Milk-O-Meter and involved the following operations: (1) The ball valve of the sampler was opened for 3 to 5 seconds with the milk valve open and the vacuum on; (2) The milk valve was then closed and the sample bottles were held under the spigot of the sampler; (3) After the sample had drained out, the ball valve was reset. This method of sampling produced approximately an ounce sample per cow per milking.

Several checks were conducted periodically during the experiment to assure as much accuracy as possible. The level of each Milk-O-Meter bracket was checked weekly with a spirit level. Prior to their use in the experiment, all meters were field-tested for accuracy (combined capacity of the rocker cups).* The tares of the spring scale and of the springless scale were also checked twice daily just prior to each milking operation.

Milk production was recorded as daily yield by combining the weights of the evening and morning milkings. The milk collected in the sampling devices of each meter was weighed and added to the daily weights of the spring scales and of the springless scale. This procedure was necessary because this amount of milk was weighed and recorded by the meter but not by the spring and springless scale at the time of milking. Untripped meter weights were used for the analysis.

RESULTS AND DISCUSSION

Variability within the Methods

Mean squares and coefficients of variation for milk weights and butterfat tests determined for the different measuring methods used are presented in Table I.

TABLE 1.—ESTIMATES OF VARIABILITY IN THE METHODS OF DETERMINING MILK YIELD AND BUTTERFAT TEST

Source of variation	Degrees of freedom	Mean squares			Coefficients of variation %		
		M	S	T	M	S	T
	Milk yield						
Weeks × treatments[1] (Experimental error)	55	18.3	18.0	18.1	14.9	14.7	14.8
Between days within weeks, levels and breeds (Sampling error)	216	2.32	2.12	2.18	5.3	5.0	5.1
		MS	CS		MS	CS	
	Butterfat test						
Weeks × treatments[1] (Experimental error)	55	0.28	0.30		11.4	11.8	
Between days within weeks, levels and breeds (Sampling error)	216	0.16	0.18		8.6	9.1	

[1] This interaction term is considered here as an estimate of week-to-week variability with treatments being breeds, levels and breeds × levels.

* Checking procedure recommended by the manufacturer of the Milk-O-Meter.

The data in Table 1 show that whether the week-to-week variability (experimental error) or the day-to-day variability (sampling error) is considered, all three methods of ascertaining milk yields gave approximately the same degree of variability measured in terms of the mean squares and the coefficients of variation. Likewise, estimates of butterfat percentage are shown to be quite uniform between the two sampling methods used. Therefore, one cannot make a choice of the methods on the basis of differences in degrees of variability about the mean.

It is of interest to note the degree of variability that prevailed between the meters employed. Table 2 contains the pertinent data for this purpose and shows that the variability was relatively small.

An analysis of the spring scale deviations revealed highly significant differences between scales. Whereas the new spring scales were on the average 0.10 pounds short (on a per cow per day basis) of the standard weight, the old dairy scales weighed on the average 0.28 pounds more

TABLE 2.—ESTIMATES OF VARIABILITY BETWEEN METERS IN THEIR MILK PRODUCTION ESTIMATES

Source of variation	Degrees of freedom	Mean squares	Coefficient of variation %
Between meters:			
(a) Within weeks, levels and breeds	72	2.02	4.9
(b) Within days, weeks, levels and breeds	144	2.47	5.5

TABLE 3.—AVERAGE DAILY MILK PRODUCTION AS DETERMINED BY THE DIFFERENT WEIGHING SYSTEMS AND DEVIATIONS OF (M) AND (S) FROM STANDARD SCALE (T)

Description		Yields			Differences	
		M	S	T	M-T	S-T
		lb.	lb.	lb.	lb.	lb.
Weeks	1	34.33	34.20	34.32	.01	−.12
	2	30.39	31.09	30.52	−.13	.57
	3	28.86	29.27	28.97	−.11	.30
	4	28.11	27.98	28.12	−.01	−.14
	5	24.91	25.17	25.11	−.20	.06
	6	25.68	25.73	25.75	−.07	−.02
Breeds	Holstein	37.82	37.99	37.90	−.08	.01
	Ayrshire	29.72	29.84	29.76	−.04	.08
	Jersey	18.58	18.84	18.70	−.12	.14
	Guernsey	28.77	28.96	28.83	−.10	.13
Levels of production	High	41.9	42.11	42.02	−.12	.09
	Medium	27.1	27.30	27.20	−.06	.10
	Low	17.1	17.30	17.17	−.07	.13
Over-all average		28.71	28.91	28.80	−.09	.11

than the standard scale. The difference of 0.38 pounds was significant at the .01 level of probability. The high and positive deviation of the old scales was probably due to spring fatigue.

The fact that the different methods gave similar precision measured in terms of variability does not mean the actual estimates of milk production and butterfat test are also necessarily similar.

Estimates of Yield by the Different Methods

The daily milk yields as determined by the three methods of weighing are presented in Table 3 according to weeks, breeds, levels of production and methods along with the differences between the M and T, and S and T methods.

A study of the data in Table 3 shows a remarkable similarity in the milk weights for the different methods from one experimental situation to another. The least consistency occurred over the weeks of the experiment. The apparent uniformity of the estimates of milk yield by the different types of measuring devices was confirmed by the absence of significant interaction mean squares in the analysis of variance of the data (Table 4). The portion of the analysis of variance which is appropriate for a study of the methods data is that of the subtreatment section concerning only methods and interactions of methods with the other factors.

The pertinent mean squares for testing the effects of the weighing methods on milk yields are presented in Table 4. None of the mean squares for interaction was significant, so comparisons can be made between the over-all means of the three methods, M, S and T. The over-all means in Table 3 show that M gave the lowest daily yield value, 28.71 pounds; S, the highest value, 28.91 pounds and T an intermediate value of 28.80 pounds. The F-test in the analysis of variance table shows the M and S averages to be significantly lower and higher respectively than the T average.

TABLE 4.—ANALYSIS OF VARIANCE OF MILK PRODUCTION DATA FOR SUBTREATMENTS

Source of variation	Degrees of freedom	Mean squares
Methods	2	2.73
M vs. T	1	1.11*
S vs. T	1	1.63*
Methods × breeds	6	.067
M vs. T × breeds	3	.037
S vs. T × breeds	3	.037
Methods × levels	4	.040
M vs. T × levels	2	.045
S vs. T × levels	2	.035
Methods × breeds × levels	12	.16
M vs. T × breeds × levels	6	.18
S vs. T × breeds × levels	6	.035
Experimental error	120	.177

* Significant at the .05 level of probability

TABLE 5.—AVERAGE BUTTERFAT PERCENTAGES FOR THE MS, THE CS METHODS AND THE DIFFERENCES BETWEEN THE TWO SAMPLING METHODS

Description		Methods		Differences
		MS	CS	MS-CS
		%	%	%
Weeks	1	4.26	4.26	.00
	2	4.44	4.40	.04
	3	4.62	4.60	.02
	4	4.73	4.74	−.01
	5	5.02	5.03	−.03
	6	4.90	4.89	.01
Breeds	Holstein	4.04	4.08	−.04
	Ayrshire	3.96	3.95	.01
	Jersey	5.90	5.89	.01
	Guernsey	4.73	4.69	.04
Levels of production	High	5.07	5.12	−.05
	Medium	4.59	4.56	.03
	Low	4.33	4.28	.03
Over-all average		4.66	4.65	.01

The observed differences of approximately 0.10 pounds (−.09 and +.11) between the averages are estimates of the differences between the methods of measuring milk yield and are not constant, hence subject to experimental variation. The extent of this variation is indicated by setting confidence limits on the differences. For the difference of −0.09 pounds between the average weights for M and T, the confidence limits are −0.16 pounds and −0.02 pounds, and for the difference of 0.11 pounds between the average weight for S and T, the confidence limits are 0.04 and 0.18 pounds

A difference of only −0.09 or +.11 pounds in daily milk production, however, would generally be considered of no practical significance. If one accepts this view then, the M method would appear to be as satisfactory as the T method or the S method of measuring milk production.

The butterfat percentages as determined by MS and CS methods are presented according to weeks, breeds, levels of production and methods of sampling along with the differences between the two methods in Table 5.

The data in Table 5 show the greatest difference to be only 5/100's per cent. Thus there is little opportunity for the differences to be inconsistent from one situation to another. The analysis of variance of the butterfat percentages is presented in Table 6 and shows no significant interactions of methods of taking samples with the other treatments. Further, the over-all difference fails to reach significance. Calculation of 95 per cent confidence limits for the over-all difference yielded values of −0.09 to +0.10 per cent. Thus, while the observed difference between the two methods was only 0.01 per cent, normal variation may allow it to range from −0.09 to +0.10 per cent.

No significant difference was found in accuracy between the two methods of taking meter samples as compared with the conventional method.

TABLE 6.—ANALYSIS OF VARIANCE OF THE PER CENT BUTTERFAT

Source of variation	Degrees of freedom	Mean squares
Methods	1	.10
Methods × breeds	3	.033
Methods × levels	2	.125
Methods × breeds × levels	6	.028
Experimental error	60	.096
Total	143	

This indicates that the amount of sample draining out of the sampler at the completion of each milking exerts no influence whatever on the butterfat test and that the sample collected according to the manufacturer's instructions is adequately mixed.

Tolerance levels as suggested by the American Dairy Science Association in 1957 as a guide to determining accuracy of any new milk weighing and sampling mechanisms, cited by Senger (1), are as follows:

(1) Butterfat tests on individual cows should be within 0.2 (+ or −) of the fat test obtained by conventional sampling methods.

(2) Daily milk weights, as compared to an accurate scale, should be within 3 per cent or one-half pound, whichever is greater, and the error should be random, so it will cancel with repeated weighings.

(2) Physical and mechanical limitations will result in occasional errors. However 90 per cent of the tests and weights should fall within the limits given here.

In this experiment, the untripped meter weights met the American Dairy Science Association accuracy requirement on both the 0.5 pounds and the 3 per cent basis. Only 62 and 83 per cent of the tripped Milk-O-Meter weights (untripped daily weight +0.5 pounds) were found to be within 0.5 pounds and 3 per cent of the standard scale's weights respectively. Spring scale weights were, on an over-all basis, found to be within the required percentage with regards to the 3 per cent tolerance, but not on the 0.5 pounds tolerance. Ninety-five per cent of the meter sample tests were within 0.2 per cent of the conventional sample tests. On this basis, the meters used in this experiment were satisfactory but the spring scales met the tolerance levels only at the 3 per cent level.

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